US005582237A

United States Patent [19]

Miyano

[11] **Patent Number: 5,582,237**

[45] **Date of Patent: Dec. 10, 1996**

[54] **APPARATUS FOR PREVENTING THERMAL DEFORMATION OF A MACHINE TOOL**

[76] Inventor: **Toshiharu Miyano**, 50 Dundee La., Barrington Hills, Ill. 60010

[21] Appl. No.: **179,629**

[22] Filed: **Jan. 11, 1994**

[51] **Int. Cl.**^{6} **F25B 29/00**; B23Q 11/14

[52] **U.S. Cl.** **165/46**; 165/47; 165/300; 165/296; 165/259; 82/900; 83/170; 62/DIG. 10; 219/201

[58] **Field of Search** .... 165/46, 47, 40, 165/39, 34, 26; 62/201, DIG. 10, 435; 83/170; 219/201; 82/900

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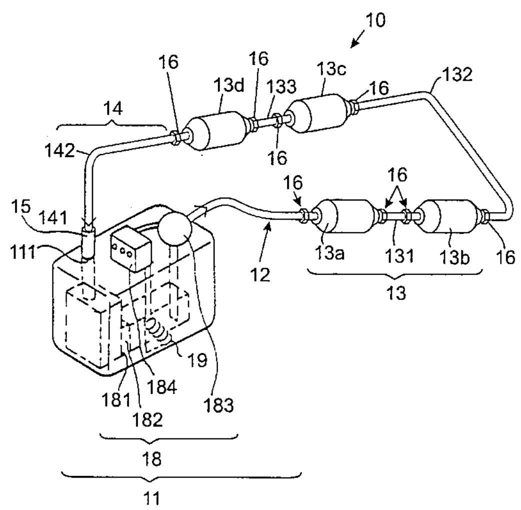
Primary Examiner—John K. Ford
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis LLP

[57] **ABSTRACT**

An apparatus for preventing thermal deformation of a machine tool has a feed unit which heats a heat transfer fluid and pumps it out to a heat exchanging portion. The heat exchanging portion has at least one heat exchanging unit capable of being expanded and shrunk in accordance with the heat transfer fluid therein. The heat exchanging unit is arranged in a prescribed portion of a machine tool. The portion of the machine tool is heated by the heat exchanging unit arranged therein, whereby thermal distribution of the machine tool is equalized and heat deformation thereof is suppressed. The heat transfer fluid passed through the heat exchanging unit is recovered by a discharging portion and fed back to the feed unit. The heat exchanging unit is maintained in an expanded state by controlling the flow rate of the fluid passing therethrough by a flow control valve, so that heat exchanging operation can be carried out effectively. The heat exchanging unit in a shrunk state can easily be arranged even in a narrow portion of the machine tool.

30 Claims, 5 Drawing Sheets



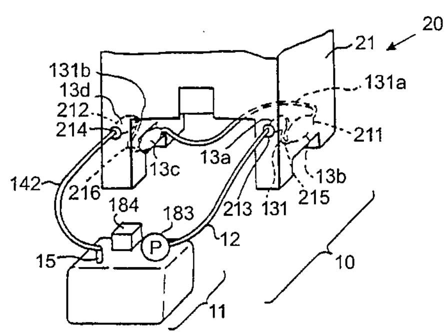


Fig. 1

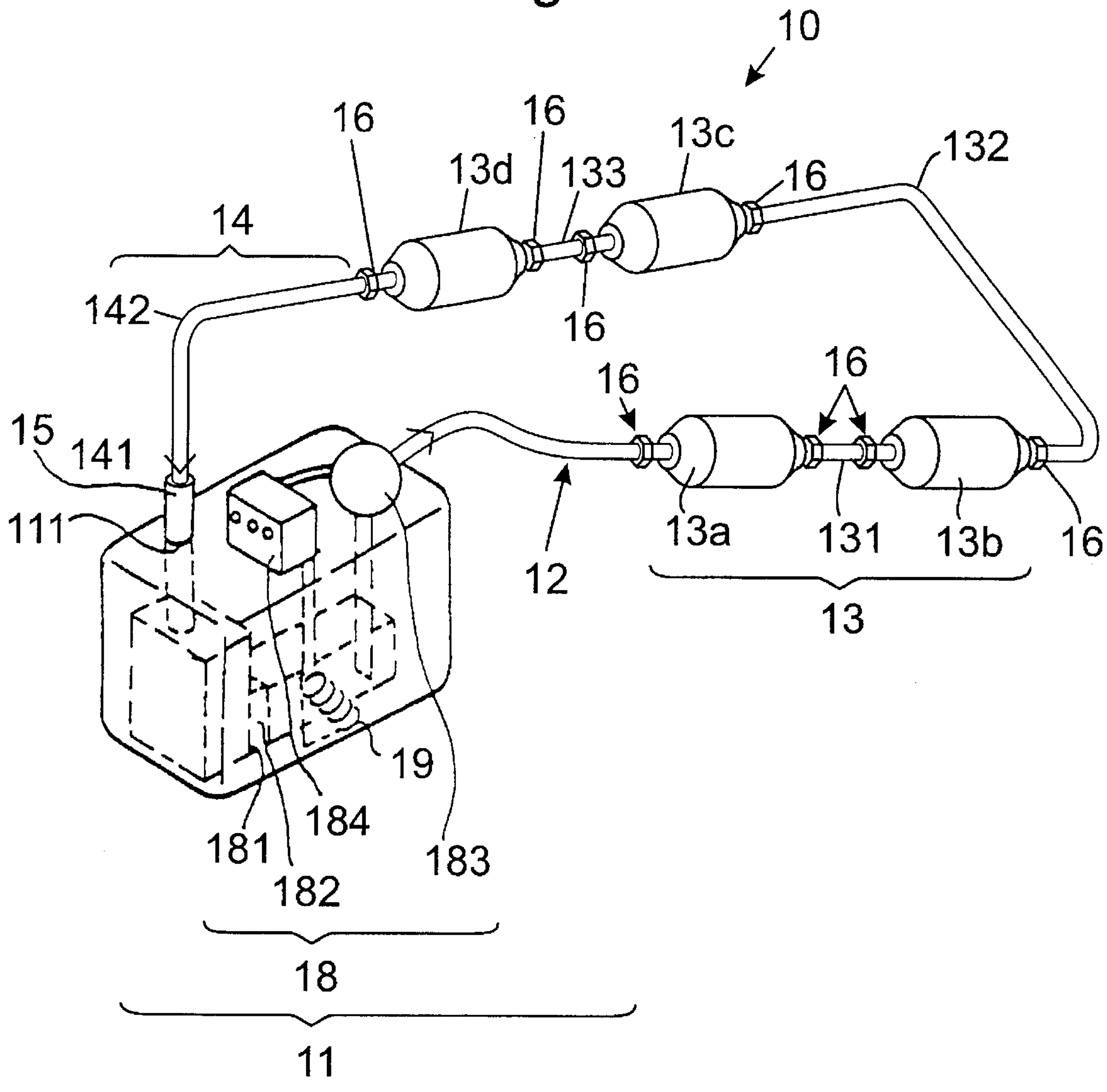

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Fig. 2

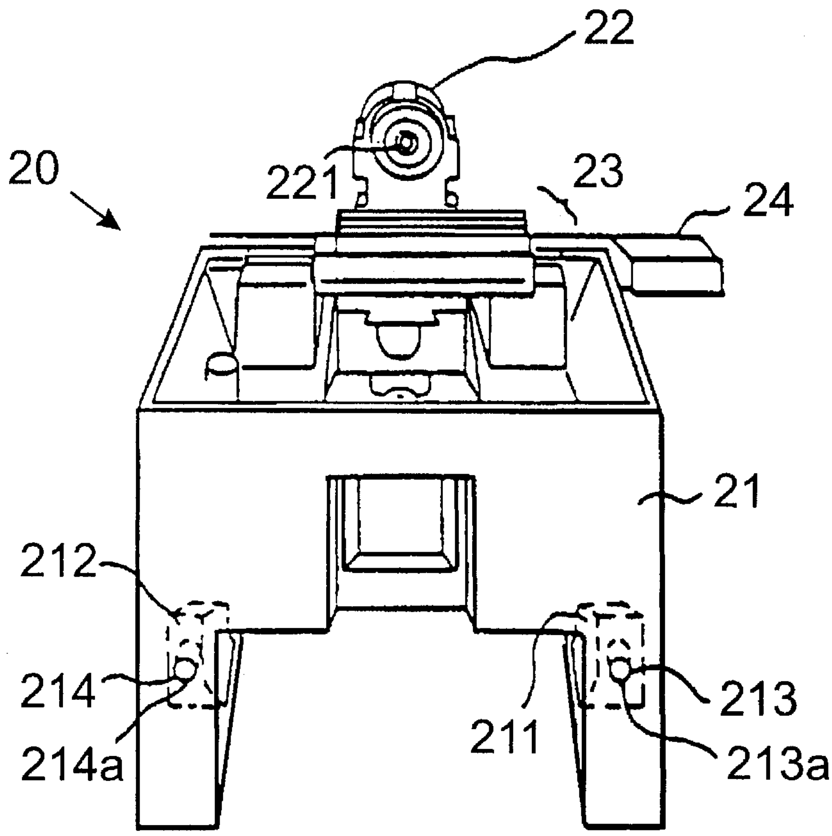
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Fig. 3

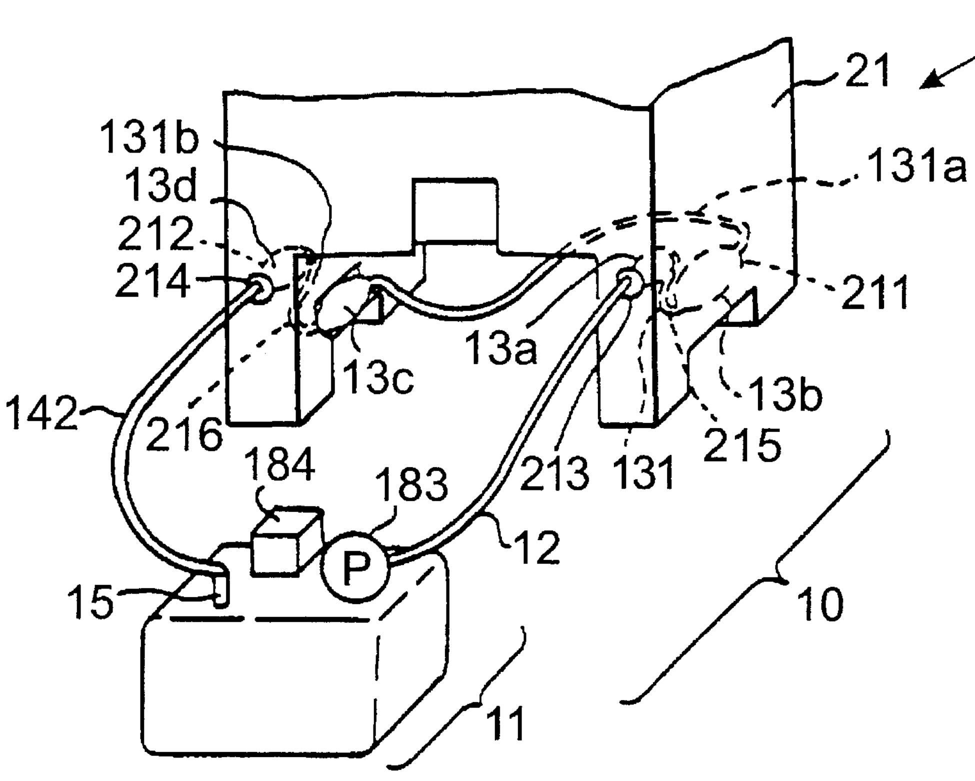
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Fig. 4

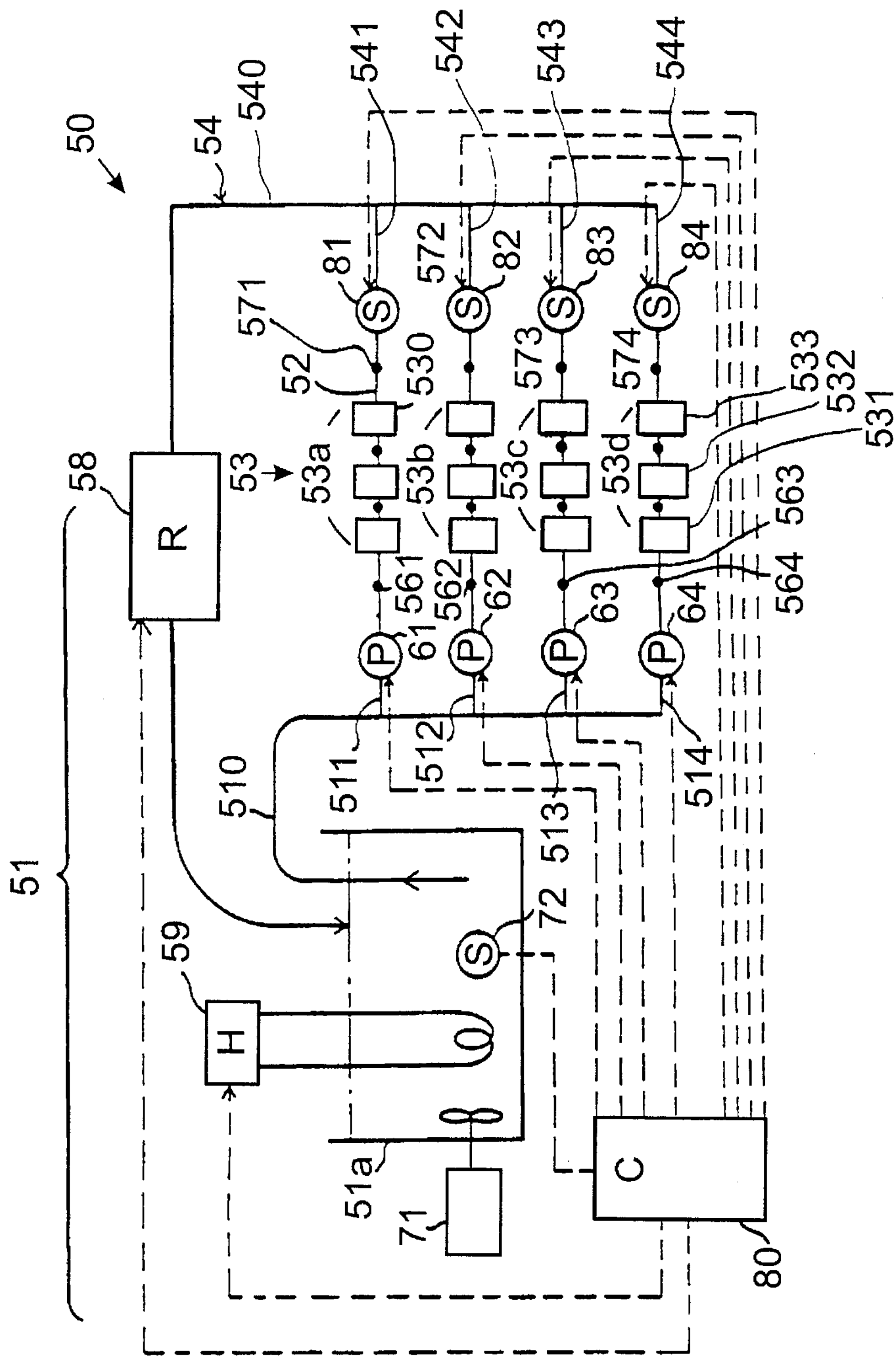
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Fig. 5

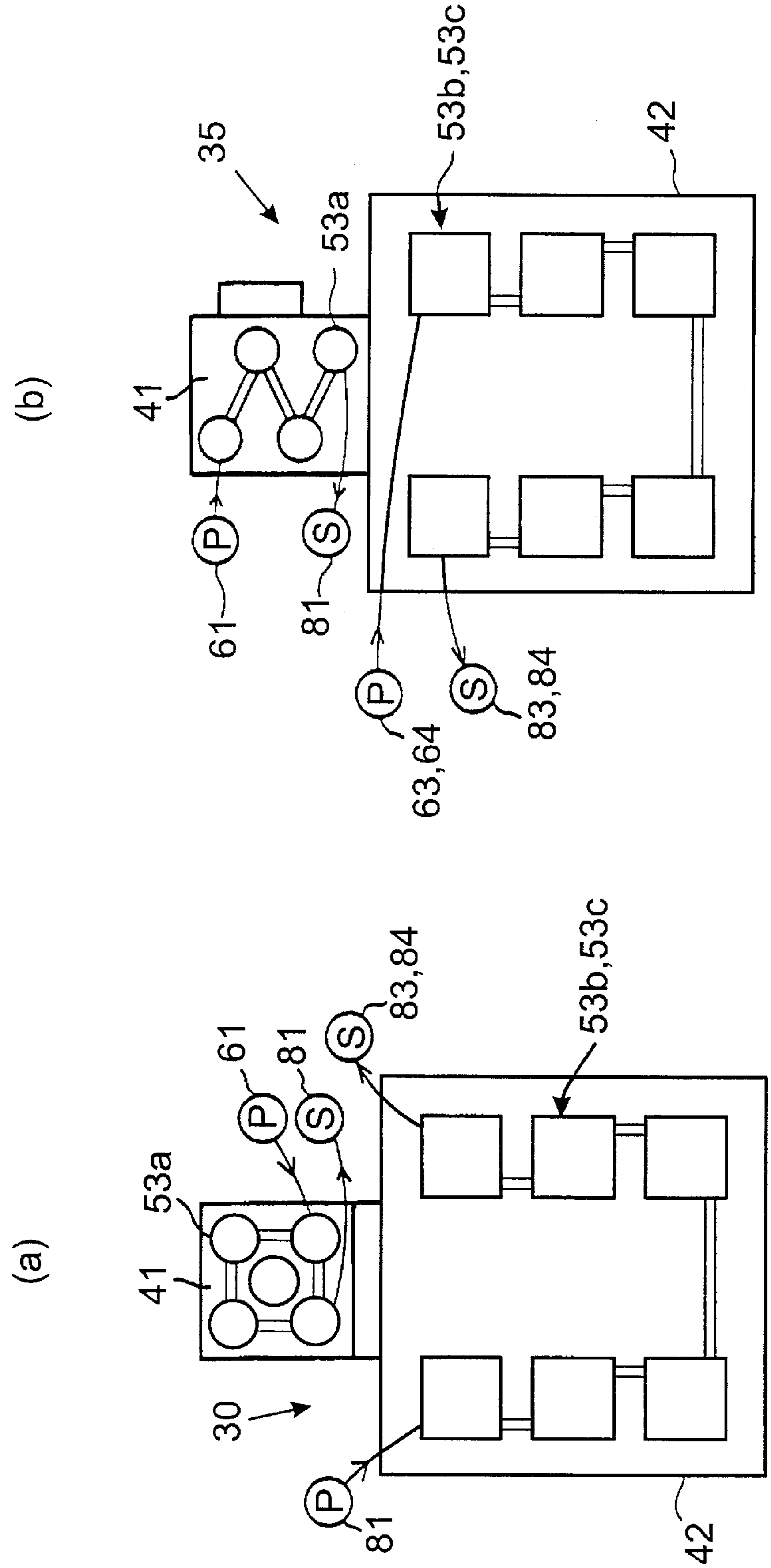
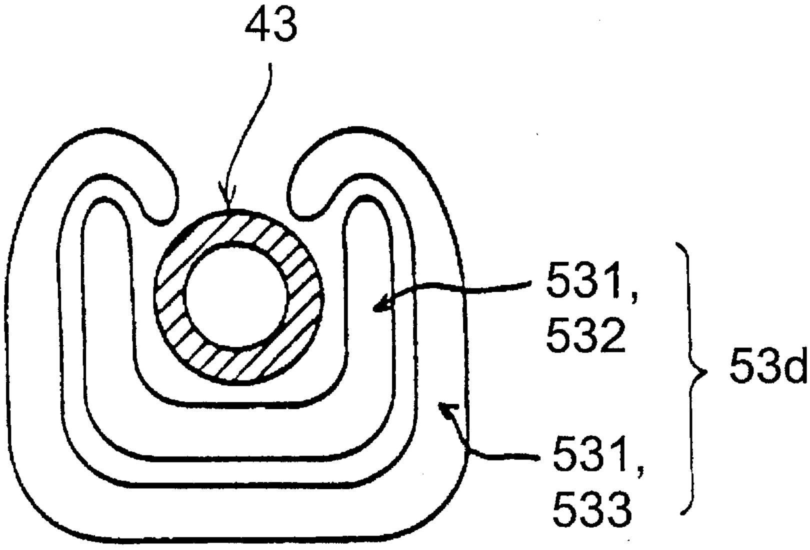


Fig. 6



APPARATUS FOR PREVENTING THERMAL DEFORMATION OF A MACHINE TOOL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an apparatus for preventing thermal deformation of a machine tool, which comprises heat exchanging portions designed to dispose in prescribed portions of the machine tool in order to prevent thermal deformation of these portions.

2. Prior Art Description

In machine tools, the electrical energy for driving thereof is inevitably consumed in part in the form of heat, so that machine tools suffer from thermal deformation. Since the thermal expansion rate of steel is as large as about 0.01 mm per meter by elevating one degree of Centigrade, thermal deformation occurred in a machine tool causes to deteriorate machining accuracy thereof. Thus, a conventional machine tool is provided with oil jackets placed around the bearing mechanism of a spindle and the like. A coolant such as a cutting oil is circulated through the oil jackets to prevent the machine tool from excessive heating, whereby the machine tool is adjusted of its thermal balance and is suppressed of its thermal deformation.

However, the provision of the oil jackets causes the machine tool complicated in structure. Further, there is a fear that the inner portions of the oil jackets will rust due to the coolant flowing therethrough. Furthermore, the portions of the machine tool which are cooled by the coolant are limited to the places where the oil jackets are provided, so that in the case that the thermal balance is changed owing to the atmosphere in which the machine tool is placed, the portions to be cooled cannot easily be modified in order to effectively suppress the thermal deformation occurred in the machine tool.

Accordingly, an object of the present invention is to provide an apparatus for preventing thermal deformation occurred in a machine tool, which is capable of suppressing the thermal deformation of the machine tool without causing the machine tool to be complicated in structure.

An another object of the present invention is to provide an apparatus for preventing thermal deformation occurred in a machine tool, which has one or more heat exchanging portions which can easily be attached on desired portions of the machine tool.

Still another object of the present invention is to provide an apparatus for preventing thermal deformation occurred in a machine tool, which is capable of heating and/or cooling desired portions of the machine tool.

Yet another object of the present invention is to provide an apparatus for preventing thermal deformation of a machine tool which is capable of performing suitable heating and/or cooling operations of the desired portions of the machine tool in accordance with an amount of heat transfer to the respective portions of the machine tool by a heat transfer fluid.

SUMMARY OF THE INVENTION

In order to achieve the above and other objects, according to the present invention, an apparatus for preventing heat deformation of a machine tool is provided, which comprises a feed means which has a heating means for heating a heat transfer fluid and a pumping out means for pumping out said heat transfer fluid heated by said heating means, a heat

exchanging means which is supplied with said heat transfer fluid from said feed means via a piping means and heats a portion of said machine tool where said heat exchanging means is to be arranged, a discharging means for discharging said heat transfer fluid passed through said heat exchanging means, and a flow control means for controlling a flow rate of said heat transfer fluid passing through said heat exchanging means, wherein said heat exchanging means is capable of being expanded and shrunk in accordance with an amount of said heat transfer fluid therein.

In a preferred embodiment of the present invention, the heat exchanging means has at least one heat exchanging unit which is bag-shaped and made of flexible material so that it is capable of being expanded and shrunk in accordance with the heat transfer fluid therein. It is preferable that the heat exchanging means is releasably connected between the feed means and the discharging means by means of joint means. Usually, the heat exchanging means has a plurality of the heat exchanging units. These heat exchanging units can be connected in serial or in parallel. It is also preferable that the discharging means is connected to the feed means so that the heat transfer fluid passed through the heat exchanging means is fed back to the feed means.

In an another preferred embodiment, a control means is provided, which detects a temperature of the heat transfer fluid when flowing into and discharging from the heat exchanging means and controls the heating means to heat the heat transfer fluid based on detected temperature of the heat transfer fluid. A cooling means for cooling the heat transfer fluid may be provided, together with the heating means. In this case, the control means is designed so that it controls to drive the heating means and the cooling means selectively based on the detected temperature of the heat transfer fluid.

In operation, the heat exchanging means is arranged in a portion of thermally lower side of the machine tool, and the heat transfer fluid is supplied to the heat exchanging means from the feed means. The portion of the machine tool where the heat exchanging means is arranged is heated by the heat transfer fluid flowing through the heat exchanging means. As a result, each portion of the machine tool becomes thermally equalized, whereby thermal deformation of the machine tool can be suppressed.

The heat exchanging means according to the present invention is capable of being expanded and shrunk according to the amount of fluid contained therein. Therefore, the heat exchanging means is set in a shrunk condition and is arranged in the portion of the machine tool. The heat exchanging means arranged in the machine tool is expanded by supplying the fluid from the feed means via the flow control means. As a result, the expanded heat exchanging means is placed in the prescribed portion of the machine tool in such a manner that the outer surface thereof is fixedly contacted with the inner surface of the portion.

Therefore, according to the present invention, the heat exchanging means can easily be placed even in a narrow portion of the machine tool. The portion of the machine tool where the heat exchanging means is to be placed can easily be changed according to the thermal condition of the machine tool. In addition, the heat transfer from the heat transfer fluid passing through the heat exchanging means to the portion of the machine tool can be carried out effectively. Further, it is not required to provide a heat exchanging mechanism such as an oil jacket in the machine tool, so that the structure of the machine tool can be simplified. Furthermore, since the machine tool is not directly contacted with the heat transfer fluid, it is prevented from rusting.

The above and other objects and advantages are apparent from reading the following description with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates schematically the constitution of a first example of the apparatus according to the present invention;

FIG. **2** is a front perspective view of a machine tool which is designed to be provided with the apparatus of FIG. **1**;

FIG. **3** is a partial perspective view of the front side of the machine tool of FIG. **2** in a condition that the apparatus of FIG. **1** is provided;

FIG. **4** is a block diagram of a second example of the apparatus according to the present invention;

FIGS. **5**(*a*) and **5**(*b*) illustrate examples of arrangement of the apparatus of FIG. **4**, respectively; and

FIG. **6** illustrates an example of arrangement of the apparatus of FIG. **4**, wherein a heat exchanging means of the apparatus is placed around the spindle of a machine tool.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

While the present invention will be described with reference to preferred embodiments, it is not intended to limit the present invention to these embodiments. On the contrary, it is intended to cover all alternatives and modifications thereof within the scope or spirit of the present invention as defined by the attached claims.

First Example

Referring now to FIG. **1**, a first example of an apparatus according to the present invention will be described. As shown in this figure, an apparatus **10** for preventing thermal deformation of a machine tool has a feed unit **11** for feeding a cooled or heated oil, and a heat exchanging portion **13** having four heat exchanging units **13***a*, **13***b*, **13***c* and **13***d* which is supplied with the oil from the feed unit **11** via a feed pipe **12** and cools or heats respective portions of a machine tool where these heat exchanging units are arranged. The apparatus **10** also has an oil discharging portion **14** which is connected to the heat exchanging unit **13***d* positioned at the most downstream side of the heat exchanging portion **13**. The oil discharging portion **14** recovers the oil passed through the heat exchanging portion **13** and feeds it back to the feed unit **11**. A flow control valve **15** is provided between the oil discharging portion **14** and the feed unit **11**, which controls the flow rate of the oil passing through the heat exchanging portion **13**.

The feed unit **11** is provided therein with an oil coolant device **18** which has an oil reservoir **181**, a filter **182** and a coolant pump **183**. The coolant pump **183** is supplied with the oil from the reservoir **181** via the filter **182**, and cools it with fluorine gas, thereafter pumps out the cooled oil to the heat exchanging portion **13**. Instead of the coolant pump **183**, a cooling device and a feed pump may be provided separately.

The feed unit **11** is also provided therein with a heater **19** for heating the oil. Where the heated oil is fed to the heat exchanging portion **13**, the coolant pump **183** is driven so that it functions only as a feed pump and at the same time the heater is driven to heat the oil. A feed pump for feeding the heated oil may be provided independently.

The coolant pump **183** and the heater **19** are controlled by a control unit **184** provided in the feed unit **11**. In the present example, under the control of the control unit **184**, the oil is fed to the heat exchanging portion **13** without being cooled where the oil temperature is detected by an appropriate means such as a bimetal thermometer that it is lower than a prescribed value such as the atmospheric temperature. While, where the oil temperature is detected that it is high above a prescribed temperature, the oil is fed to the heat exchanging portion **13** without heated.

In addition, the feed unit **11** is provided with a level meter or a float switch (not shown) for monitoring the amount of oil stored in the reservoir **181**. The coolant pump **183** has a bypass type cleaner (not shown).

The oil reservoir **181** of the feed unit **11** has an oil recovery port **111** which is connected via the flow control valve **15** to an oil discharging port **141** of an oil discharging pipe **142** constituting the oil discharging portion **14**. With the flow control valve **15** provided, the flow rate of the oil circulating through the heat exchanging portion **13** can be adjusted.

Next, the constitution of the heat exchanging portion **13** will be described. In the present example, the heat exchanging portion **13** has four heat exchanging units **13***a*, **13***b*, **13***c* and **13***d* of the same size and structure. These heat exchanging units are bag-shaped and made of low stretchable, flexible material so that they are expandable or shrinkable in accordance with the flow rate of the oil passing therethrough. In FIG. **1**, the respective heat exchanging units are shown in an expanded state, wherein the respective units are fusiformed generally. The heat exchanging units may be made in any other appropriate form so long as they are expandable and shrinkable in accordance with the flow rate of the oil passing therethrough.

In the present example, the heat exchanging units **13***a* to **13***d* are connected in serial. That is, the first heat exchanging unit **13***a* is connected at its outlet port via a feed pipe **131** to an inlet port of the adjacent second heat exchanging unit **13***b*, which, in turn, is connected at its outlet port via a feed pipe **132** to an inlet port of the third heat exchanging unit **13***c*. Likewise, an outlet port of the third heat exchanging unit **13***c* is connected via a feed pipe **133** to an inlet port of the fourth heat exchanging unit **13***d*. An inlet port of the first heat exchanging unit **13***a* is connected via the feed pile **12** to the feed unit **11**, while an outlet port of the fourth heat exchanging unit **13***d* is connected via the discharging pipe **142** to the feed unit side. The pipes **131** to **133**, **12**, and **142** are flexible and are easily arranged in and around a machine tool.

The flexible feed pipes **131** to **133** are releasably connected to the respective heat exchanging units **13***a* to **13***d*. For example, the second heat exchanging unit **13***b* is provided at its inlet and outlet ports with pipe joints **15**, **15**. The pipe joint **16** has a collar and retaining projection extending inwardly from the collar. By inserting the pipe in the collar of the joint **16**, the retaining projection engages with the outer circumferential surface of the pipe to form an automatic connection between the joint and the pipe. The pipe can be automatically removed from the joint **16** by pushing the collar of the joint inwardly so that the projection move to a non-engaging position with the pipe. In the present example, the pipes **12** and **142** are also releasably connected to the heat exchanging units **13***a* and **13***d*, respectively. The joint **16** may be of any other suitable conventional structure so long as it forms releasable connection.

FIGS. **2** and **3** show a machine tool, to which the apparatus **10** of the present example can be provided. A machine tool **20** has a base **21** made of cast iron, on which a headstock **22** and a slide table unit **23** are mounted. A feed

motor **24** is provided at the side of the slide table unit **23** for driving the table **23** to slide. At the rear side of the headstock **22** and the table unit **23**, a driving motor for a spindle **221** of the headstock **22** and the like are mounted.

The electrical power supplied to the machine tool **20** is partially consumed in the form of thermal energy, so that the machine tool is heated and suffered from thermal deformation. The thermal deformation occurred in the machine tool adversely affects the machining accuracy thereof or the like. In order to suppress the heat deformation of the machine tool, it has been proposed to design the base so as to exhibit a heat symmetry, or to provide an oil jacket around the bearing mechanism of the spindle to remove the heat generated therefrom. However, even if these conventional methods are adopted, it cannot always be expected to suppress the heat deformation of the machine tool satisfactory, since the places for providing the oil jackets in the machine tool are sometimes limited. Whereas, the heat deformation of the machine tool **20** can effectively be suppressed by the provision of the apparatus **10** of the present example.

Among the respective portions of the machine tool **20**, the headstock **22** having the spindle rotating at a high speed is one that generates the largest amount of heat. If the heat symmetry of the base **21** is deteriorated by the heat generated from the headstock **22**, the heat deformation occurs in the machine tool **20**. In order to prevent or suppress such a heat deformation of the machine tool **20**, the apparatus **10** is, for example, provided to the machine tool **20** so as to heat the low temperature side of the base **21**. In the following, the oil having a temperature maintained at around 40 degrees of Centigrade is circulated through the heat exchanging portion **13** to heat the low temperature side of the machine tool **20**.

In the present example, the machine tool **20** is designed to accommodate four heat exchanging units **13*a*** to **13*d***. For this purpose, the machine tool **20** has the base **21** provided therein with two recessed portions **211**, **212** and two void portions **213**, **214**. The recessed portions **211** and **212** are formed on the inner sides of leg portions of the base **21**. The recessed portions **211**, **212** and the void portions **213**, **214** can by formed by any one of conventional appropriate methods. As can be seen from FIG. **3**, the void portions **213** and **214** have openings **213*a*** and **214*a***, respectively, exposing from the front surface of the base **21**. The void portion **213** is linked via a passage **215** formed in the base **21** to the recessed portion **211**. Likewise, the other void portion **214** is linked via a passage **216** formed in the base **21** to the recessed portion **212**. Although the machine too **20** has four places for receiving the heat exchanging units **13*a*** to **13*d***, the number of places for receiving the heat exchanging units can be varied according to the number of portions of machine tool to be heated or cooled.

The heat exchanging units **13*a*** to **13*d*** are arranged in the respective portions **211** to **214** as follows. First, the respective heat exchanging units **13*a*** to **13*d*** are disassembled from the feed unit **11** by removing the feed pipes **12**, **131** to **133** and the discharging pipe **142**. Then, the first and fourth heat exchanging units **13*a*** and **13*d*** are inserted into the void portions **213** and **214**, respectively, through the openings **213*a*** and **214*a***. Since these void portions **213** and **214** are small in size compared to these heat exchanging units **13*a*** and **13*d*** in the expanded state shown in FIG. **1**, these heat exchanging units **13*a*** and **13*d*** are shrank to a certain degree by discharging oil or air contained therein so as to be able to insert into the respective void portions **213** and **214**. When inserting into the void portion **213**, the heat exchanging unit **13*a*** is connected with the feed pipe **131** beforehand and is inserted into the void portion **213** from the side of the

connected feed pipe **131**. Thus, the heat exchanging unit **13*a*** and the feed pipe **131** are arranged in the void portion **213** and the passage **215**, respectively. Insertion of the heat exchanging unit **13*d*** and the feed pipe **133** is carried out in the same manner as that of the heat exchanging unit **13*a*** and the feed pipe **131**.

Then, the second and third heat exchanging units **13*b*** and **13*c*** are inserted into the corresponding recessed portions **211** and **212**, and thereafter they are connected with each other by the feed pipe **133**. In addition, the heat exchanging units **13*b*** and **13*c*** are connected to the feed pipes **131** and **133** formerly arranged in the base **21**. Finally, the first and fourth heat exchanging units **13*a*** and **13*d*** are connected with the feed pipe **12** and the discharging pipe **142**, respectively. As a result, the apparatus **10** of FIG. **1** where the four heat exchanging units **13*a*** to **13*d*** are connected in serial is arranged in the machine tool **20**.

In operation, the heated oil is supplied from the feed unit **11** and circulated through the four heat exchanging units **13*a*** to **13*d***. Since the flow rate of the oil circulating through the heat exchanging units **13*a*** to **13*d*** is controlled by the control valve **15** inserted between the discharging pipe **142** and the feed unit **11**, the respective heat exchanging units **13*a*** to **13*d*** are maintained in an expanded state, so that the outer surfaces of the respective units are set fixedly contacted with the inner surfaces of the portions **211** to **214** of the machine tool **20** where these units are accommodated. Therefore, in each of the heat exchanging units **13*a*** to **13*d***, heat exchanging operation is effectively carried out between the oil supplied thereto and the portion of the machine tool. Thus, even if the portion of the machine tool **20** where the headstock **22** is mounted is heated during the operation thereof, the heat symmetry of the base **21** is maintained since the low temperature side of the base **21** is heated by the heat exchanging units **13*a*** to **13*d***.

It has been found that, according to experiments conducted by the inventor of the present invention, the heat deformation of the machine tool **20** can be suppressed to at least 25% of that occurred in the machine tool without the apparatus of the present example and that the machining accuracy thereof can be maintained.

In the present example, the machine tool **20** is heated by the heat exchanging units **13*a*** to **13*d***. Alternatively, the machine tool **20** may be cooled by the heat exchanging units arranged in portions of high temperature side of the machine tool so that the machine tool is prevented from heat deforming. In this case, the heat exchanging units **13*a*** to **13*d*** are supplied with oil cooled by the oil coolant pump **183**.

As described above, since the machine tool **20** of the present example is heated at its low temperature side by the heat exchanging units **13*a*** to **13*d*** provided therein, the heat deformation thereof can be suppressed without provision of a cooling oil jacket or with a minimum provision of such a cooling oil jacket. In addition, the oil circulating through the heat exchanging units **13*a*** to **13*d*** does not directly contact with the respective portions of the machine tool **20**, so that it does not cause to rust these portions of the machine tool. Further, even if the heat distribution of the machine tool **20** is varied due to the change in atmosphere thereof or the like, the positions of the heat exchanging units **13*a*** to **13*d*** arranged in the machine tool can easily be changed accordingly, whereby the heat symmetry of the machine tool can be maintained irrespective of the change in atmosphere of the machine tool. Furthermore, according to the present example, the feed unit **11** of the apparatus **10** has cooling and heating means for oil, so that cooling and/or heating of the machine tool can be carried out selectively.

Since the heat exchanging units **13**_a_ to **13**_d_ of the apparatus **10** are in the from of bag made of stretchable material and is capable of being expanded or shrunk, they can easily be inserted into prescribed narrow portions of the machine tool in a shrunk state. Further, these heat exchanging units are maintained in an expanded state in operation, so that they are fixedly contacted with the portions of the machine tool. Therefore, the machine tool can effectively be cooled or heated by the heat exchanging units.

In addition, since the heat exchanging units **13**_a_ to **13**_d_ and the corresponding feed pipes are releasably connected with each other by means of the pipe joints **16**, it is easy to connect a desired number of heat exchanging units and assemble in the machine tool. Further, according to the present example, the oil is circulated between the feed unit **11** and the heat exchanging units **13**_a_ to **13**_d_, and therefore a limited amount of oil can be used effectively.

In the present example, the flow control valve **15** is provided to control the flow rate of the oil circulating through the heat exchanging units **13**_a_ to **13**_d_. Alternatively, the flow rate of the oil can be adjusted, for example, by controlling the feed rate of oil from the coolant pump **183** in accordance with the discharging rate of oil from the discharging portion **14**. The heat exchanging units can be connected in serial or in parallel. The connecting mode of the heat exchanging units, the number thereof and the like depend on the size or structure of the machine tool to which the heat exchanging units are assembled, and so they are not limited to those of the present example. In addition, although the heat exchanging units are arranged in the base of the machine tool according to the present example, they may be arranged other than these portions of the machine tool. They may be arranged, for example, in the surroundings of the headstock **22**, openings in the sliding table **23** and the like. The positions of the heat exchanging units are assembled are determined in accordance with the thermal distribution of the machine tool, which are not limited to the present example so long as the thermal deformation of the machine tool can be suppressed effectively.

In addition, according to the present example, the oil fed to the heat exchanging units is cooled by utilizing the coolant pump **183**. A means for cooling oil is not limited to the coolant pump, but may be any other suitable means. The heater **19** may be replaced by any other suitable means. Further, either one of cooling means or heating means may be eliminated from the feed unit **11**.

Furthermore, according to the present example, the control of cooling and heating the oil in the feed unit **11** is carried out based on the ambient temperature. Instead, this can be carried out by detecting continuously or intermittently the temperatures of the respective portions of the machine tool to be cooled or heated and controlling the temperature of oil based on the detected temperatures.

Second Example

FIG. **4** is a schematic diagram of an apparatus for preventing heat deformation of a machine tool according to the second example of the present invention. The apparatus **50** comprises a feed unit **51** which has a water reservoir **51**_a_, a heater **59** for heating water stored in the reservoir **51**_a_, a stirring machine **71** for stirring water in the reservoir **51**_a_ and a sensor **72** for detecting a temperature of water in the reservoir **51**_a_. An outlet port of the reservoir **51**_a_ is connected via a feed pipe **510** and four branch pipes **511** to **514** therefrom to the suction ports of feed pumps **61** to **64**. The respective pumps **61** to **64** are connected at their discharging ports with feed pipes **521** to **524**, which in turn are releasably connected to a heat exchanging portion **53** by means of pipe joints **561** to **564**.

The heat exchanging portion **53** comprises four heat exchanging units **53**_a_ to **53**_d_ of the same structure. Each of the heat exchanging units **53**_a_ to **53**_d_ includes three heat exchanging bags **531** to **533**. The respective heat exchanging units **53**_a_ to **53**_d_ are releasably connected at their exit sides with branch pipes **541** to **544** by means of pipe joints **571** to **574**, respectively. These branch pipes **541** to **544** are connected to a discharging pipe **542** constituting the discharging portion **54**. The branch pipes **541** to **544** are provided with sensors **81** to **84** for detecting the temperatures of water discharging from the respective heat exchanging units **53**_a_ to **53**_d_. The discharging pipe **540** is connected via a radiator **58** to the reservoir **51**_a_ of the feed unit **51**. The radiator **58** of the present example can be adjusted of its cooling capability by controlling the rotational speed of a motor fan thereof.

As can be seen from FIG. **4**, the heat exchanging units **53**_a_ to **53**_d_ are connected in parallel between the feed unit **51** and the discharging portion **54**. Each of the heat exchanging units **53**_a_ to **53**_d_ includes three heat exchanging bags **531** to **533** connected in serial having the same structure as those of the heat exchanging units **13**_a_ to **13**_d_ of the first example as described above. More specifically, each of the bags **531** to **533** is formed by a flexible sheet material made of resin, rubber or the like, and is capable of being expanded or shrunk in accordance with the amount of water passing therethrough. The bags **531** to **533** constituting each of the heat exchanging unit **53**_a_ to **53**_d_ are releasably connected by means of pipe joints having the same structure as those of the pipe joints **561** to **564**. Instead of providing a plurality of heat exchanging bags, one or more of the heat exchanging units **53**_a_ to **53**_d_ may be comprised by a single heat exchanging bag.

The feed unit **51** is also provided with a control unit **80** which monitors the change in temperature of water between flowing into and discharging from the heat exchanging portion **53** based on the outputs of the respective sensors **72** and **81** to **84**. In addition, the control unit **80** controls the respective pumps **61** to **64** to adjust the feed rate of water to the heat exchanging portion **54**, and also controls the heater **59** and radiator **58**.

FIGS. **5**(_a_) and **5**(_b_) illustrate the apparatus **50** of the present example being arranged in a lathe **30** and a milling machine **35**, respectively. In both cases, among the heat exchanging units **53**_a_ to **53**_d_, the first heat exchanging unit **53**_a_ is arranged in respective body portions **41** of the lathe **30** and the milling machine **35**, and the second and third heat exchanging units **53**_b_ and **53**_c_ are arranged in respective bases **42** thereof. The remaining heat exchanging unit **53**_d_ is arranged around respective spindle portions **43** as shown in FIG. **6**, wherein since excessive heat generation occurs in the spindle portion **43**, two or more heat exchanging bags **531** to **533** constituting the heat exchanging unit **53**_d_ are wound around the spindle portion **43** in an overlapped condition so as to prevent heat generated from the spindle portion **43** from transferring to the surrounding portions thereof. Other than the spindle portion **43**, it is preferable to wind the heat exchanging bags in an overlapped condition around those portions as the surroundings of the motor, the recovery portion of cutting oil, the surroundings of the hydraulic tank and the like generating an excessive amount of heat.

After assembling the apparatus **50** of the present example to the lathe or the milling machine as shown in FIGS. **5**(_a_), **5**(_b_) and **6**, the respective heat exchanging units **53**_a_ to **53**_d_

are supplied with water of prescribed temperature as a heat transfer fluid from the feed unit **51**, whereby the spindle portion **43**, the body portion **41** and the base **42** are cooled or heated by the water passing through the corresponding heat exchanging units so that the temperatures of these portions are equalized. More specifically, the surroundings of the spindle **43** is cooled by the heat exchanging unit **53***d* as it generates an excessive amount of heat, while the base **42** is heated by water passing through the heat exchanging units **53***b* and **53***c* as it does not generate heat. Accordingly, the respective portions of the machine tool is equalized in temperature and therefore the thermal deformation of the machine tool can be suppressed.

According to the present example, the temperature of water is detected when flowing into and discharging from the respective heat exchanging units **53***a* to **53***d* by means of sensors **81** to **84**. Based on the outputs of the sensors, the controller **80** calculates the heat capacity of water and controls the radiator **58** and the heater **59** so that the temperature of water circulating through the heat exchanging units is maintained to be constant. That is, where the water absorbs a certain amount of heat from the machine tool that is larger than that of heat discharged from the water to the machine tool, an amount of heat corresponding to the difference therebetween must be discharged from the water through the radiator **58**. The amount of heat which must be discharged can be determined as the enthalpy change measured from the change in temperature of water between flowing into and discharging from each of the heat exchanging units and the specific heat of water. Hence, the total amount of heat which must be discharged from water through the radiator can be calculated as the sum of enthalpy change in each of the heat exchanging units. Based on the calculated value, the controller **80** controls to drive the radiator **58** so as to maintain the temperature of water to be constant. On the other hand, if the amount of heat discharging from the water is larger, an amount of heat corresponding to the difference therebetween is applied to the water to thereby maintain the temperature of water to be constant.

As described above, according to the apparatus **50** of the present example, such effects as those of the first example of the present invention can be obtained, that is, the heat deformation of the machine tool can be suppressed without providing cooling oil jacket therein, the heat exchanging units are arranged in narrow spaces in the machine tool since they can be shrunk, and the like. In addition, since the controller **80** monitors an amount of heat discharged from or absorbed into the water based on the outputs of the sensors **81** to **84**, and **72**, and controls to heat or cool the water, so that the temperature of the water can be maintained to be constant. According to the survey of the inventor of the present invention, the machining accuracy of the machine tool which is provided with the apparatus **50** of the present example was found to be enhanced to be six times as high as that obtained without providing the apparatus **50**.

As mentioned above, the apparatus for preventing heat deformation of a machine tool according to the present invention is characterized in that the heat exchanging portion for controlling the temperature of the desired portions of the machine tool is capable of being expanded or shrunk. Therefore, according to the present invention, since desired portions of the machine tool can be cooled or heated easily and effectively, the deformation of the machine tool can be suppressed without the provision of conventional cooing oil jackets or with a minimum provision thereof. In addition, the heat transfer fluid such as oil, water or the like does not directly contact the respective portions of the machine tool, so that the machine tool is prevented from rusting by the fluid. Further, even if the thermal distribution of the machine tool is changed due to the change in atmosphere where the machine tool is placed, the position of the heat exchanging portion attached to the machine tool can easily be modified in order to compensate the change in the thermal distribution. Furthermore, since the heat exchanging portion can be expanded or shrunk, it can easily be arranged even in a narrow space of the machine tool, and thus the limitation to places where the heat exchanging portions are provided can be minimized. In addition, the heat exchanging portion is arranged in a fixedly contacted state to the machine tool, so that an effective heating or cooling can be carried out.

On the other hand, according to the present invention, a plurality of heat exchanging portions are releasably connected in serial or in parallel by means of the pipe joints. Therefore, a plurality of portions of the machine tool can be cooled or heated by the apparatus of the present invention. In addition, the change of portions to be cooled or heated can easily be carried out.

Further, where the discharging portion is connected to the feed unit to circulate the heat transfer fluid through the feed unit and the heat exchanging portion, a small amount of heat transfer fluid can be used economically.

I claim:

1. An apparatus for preventing heat deformation of a machine tool comprising a feed means which has a heating means of a heat transfer fluid and a pumping out means for pumping out said heat transfer fluid heated by said heating means, a heat exchanging means which is supplied with said heat transfer fluid from said feed means via a piping means and heats a portion of said machine tool where said heat exchanging means is to be arranged, a discharging means for discharging said heat transfer fluid passed through said heat exchanging means, and a flow control means for controlling a flow rate of said heat transfer fluid passing through said heat exchanging means, wherein said heat exchanging means has at least one heat exchanging unit which is made entirely of a flexible material so that it is capable of being expanded and shrunk in accordance with an amount of said heat transfer fluid therein.

2. An apparatus for preventing heat deformation of a machine tool according to claim **1**, wherein said heat exchanging means has at least one heat exchanging unit which is bag-shaped so that it is capable of being expanded and shrunk in accordance with said heat transfer fluid therein.

3. An apparatus for preventing heat deformation of a machine tool according to claim **2**, wherein said heat exchanging means is releasably connected between said feed means and said discharging means by means of joint means.

4. An apparatus for preventing heat deformation of a machine tool according to claim **3**, wherein said heat exchanging means has a plurality of said heat exchanging units connected serially and releasably by means of joint means, said heat exchanging units being intended to be arranged in different portions of said machine tool.

5. An apparatus for preventing heat deformation of a machine tool according to claim **3**, wherein said heat exchanging means has a plurality of said heat exchanging units connected in parallel between said feed means and said discharging means, said heat exchanging units being intended to be arranged in different portions of said machine tool.

6. An apparatus for preventing heat deformation of a machine tool according to claim **1**, wherein said discharging means is connected to said feed means so that said heat

transfer fluid passed through said heat exchanging means is fed back to said feed means.

7. An apparatus for preventing heat deformation of a machine tool according to claim 6, further comprising a control means which detects a temperature of said heat transfer fluid when flowing into and discharging from said heat exchanging means and controls said heating means to heat said heat transfer fluid based on detected temperature of said heat transfer fluid.

8. An apparatus for preventing heat deformation of a machine tool according to claim 7, wherein said feed means has a cooling means for cooling said heat transfer fluid and wherein said control means controls to drive said heating means and said cooling means selectively based on said detected temperature of said heat transfer fluid.

9. An apparatus for preventing heat deformation of a machine tool comprising a feed means which has a cooling means for cooling a heat transfer fluid and a pumping out means for pumping out said heat transfer fluid cooled by said cooling means, a heat exchanging means which is supplied with said heat transfer fluid from said feed means via a piping means and cools a portion of said machine tool where said heat exchanging means is to be arranged, a discharging means for discharging said heat transfer fluid passed through said heat exchanging means, and a flow control means for controlling a flow rate of said heat transfer fluid passing through said heat exchanging means, wherein said heat exchanging means has at least one heat exchanging unit which is made entirely of a flexible material so that it is capable of being expanded and shrunk in accordance with an amount of said heat transfer fluid therein.

10. An apparatus for preventing heat deformation of a machine tool according to claim 9, wherein said heat exchanging means has at least one heat exchanging unit which is bag-shaped so that it is capable of being expanded and shrunk in accordance with said heat transfer fluid therein.

11. An apparatus for preventing heat deformation of a machine tool according to claim 10, wherein said heat exchanging means is releasably connected between said feed means and said discharging means by means of joint means.

12. An apparatus for preventing heat deformation of a machine tool according to claim 11, wherein said heat exchanging means has a plurality of said heat exchanging units connected serially and releasably by means of joint means, said heat exchanging units being intended to be arranged in different portions of said machine tool.

13. An apparatus for preventing heat deformation of a machine tool according to claim 11, wherein said heat exchanging means has a plurality of said heat exchanging units connected in parallel between said feed means and said discharging means, said heat exchanging units being intended to be arranged in different portions of said machine tool.

14. An apparatus for preventing heat deformation of a machine tool according to claim 9, wherein said discharging means is connected to said feed means so that said heat transfer fluid passed through said heat exchanging means is fed back to said feed means.

15. An apparatus for preventing heat deformation of a machine tool according to claim 14, further comprising a control means which detects a temperature of said heat transfer fluid when flowing into and discharging from said heat exchanging means and controls said cooling means to cool said heat transfer fluid based on detected temperature of said heat transfer fluid.

16. A machine tool having an apparatus for preventing heat deformation of said machine tool characterized in that:

said apparatus for preventing heat deformation of a machine tool comprises a feed means which has a heating means of a heat transfer fluid and a pumping out means for pumping out said heat transfer fluid heated by said heating means, a heat exchanging means which is supplied with said heat transfer fluid from said feed means via a piping means, a discharging means for discharging said heat transfer fluid passed through said heat exchanging means, and a flow control means for controlling a flow rate of said heat transfer fluid passing through said heat exchanging means, wherein said heat exchanging means has at least one heat exchanging unit which is made entirely of a flexible material so that it is capable of being expanded and shrunk in accordance with an amount of said heat transfer fluid therein, and that,

said machine tool has at least one portion in which said heat exchanging means is accommodated, whereby said portion is heated by said heat exchanging means so as to equalize thermal distribution of said machine tool and suppress thermal deformation thereof.

17. A machine tool according to claim 16, wherein said heat exchanging means has at least one heat exchanging unit which is bag-shaped that it is capable of being expanded and shrunk in accordance with said heat transfer fluid therein.

18. A machine tool according to claim 17, wherein said heat exchanging means is releasably connected between said feed means and said discharging means by means of joint means.

19. A machine tool according to claim 18, wherein said heat exchanging means has a plurality of said heat exchanging units connected serially and releasably by means of joint means, and wherein said machine tool has a plurality of said portions in which said heat exchanging units are accommodated.

20. A machine tool according to claim 18, wherein said heat exchanging means has a plurality of said heat exchanging units connected in parallel between said feed means and said discharging means, and wherein said machine tool has a plurality of said portions in which said heat exchanging units are accommodated.

21. A machine tool according to claim 16, wherein said discharging means is connected to said feed means so that said heat transfer fluid passed through said heat exchanging means is fed back to said feed means.

22. A machine tool according to claim 21, further comprising a control means which detects a temperature of said heat transfer fluid when flowing into and discharging out said heat exchanging means and controls said heating means to heat said heat transfer fluid based on detected temperature of said heat transfer fluid.

23. A machine tool according to claim 22, wherein said feed means has a cooling means for cooling said heat transfer fluid and where in said control means controls to drive said heating means and said cooling means selectively based on said detected temperature of said heat transfer fluid.

24. A machine tool having an apparatus for preventing heat deformation of said machine tool characterized in that:

said apparatus for preventing heat deformation of a machine tool comprises a feed means which has a cooling means for cooling a heat transfer fluid and a pumping out means for pumping out said heat transfer fluid cooled by said cooling means, a heat exchanging means which is supplied with said heat transfer fluid from said feed means via a piping means, a discharging means for discharging said heat transfer fluid passed

through said heat exchanging means, and a flow control means for controlling a flow rate of said heat transfer fluid passing through said heat exchanging means, wherein said heat exchanging means has at least one heat exchanging unit which is made entirely of a flexible material so that it is capable of being expanded and shrunk in accordance with an amount of said heat fluid therein, and that,

said machine tool has at least one portion in which said heat exchanging means is accommodated, whereby said portion is cooled by said heat exchanging means so as to equalize thermal distribution of said machine tool and suppress thermal deformation thereof.

25. A machine tool according to claim **24**, wherein said heat exchanging means has at least one heat exchanging unit which is bag-shaped so that it is capable of being expanded and shrunk in accordance with said heat transfer fluid therein.

26. A machine tool according to claim **25**, wherein said heat exchanging means is releasably connected between said feed means and said discharging means by means of joint means.

27. A machine tool according to claim **26**, wherein said heat exchanging means has a plurality of said heat exchang-

ing units connected serially and releasably by means of joint means, and wherein said machine tool has a plurality of said portions in which said heat exchanging units are accommodated.

28. A machine tool according to claim **26**, wherein said heat exchanging means has a plurality of said heat exchanging units connected in parallel between said feed means and said discharging means, and wherein said machine tool has a plurality of said portions in which said heat exchanging units are accommodated.

29. A machine tool according to claim **24**, wherein said discharging means is connected to said feed means so that said heat transfer fluid passed through said heat exchanging means is fed back to said feed means.

30. A machine tool according to claim **29**, further comprising a control means which detects a temperature of said heat transfer fluid when flowing into and discharging out said heat exchanging means and controls said cooling means to cool said heat transfer fluid based on detected temperature of said heat transfer fluid.

* * * * *

US005673467A

United States Patent [19]

Miyano et al.

[11] **Patent Number:** 5,673,467

[45] **Date of Patent:** Oct. 7, 1997

[54] **MACHINE TOOL ASSEMBLY**

[76] Inventors: **Shigemori Steven Miyano; Toshiharu Miyano**, both c/o Miyano Machinery USA Inc., 940 N. Central Ave., Wood Dale, Ill. 60191

[21] Appl. No.: **329,642**

[22] Filed: **Oct. 26, 1994**

[51] **Int. Cl.**^{6} **B23Q 5/04**; B23B 3/00; G05B 11/18

[52] **U.S. Cl.** .... **29/27 C**; 82/110; 173/12; 408/129; 318/594

[58] **Field of Search** .... 409/231; 483/54; 29/40, 27 C; 408/129, 16; 82/110, 145; 318/594, 49; 74/424.8 B; 60/53 R; 173/12, 163

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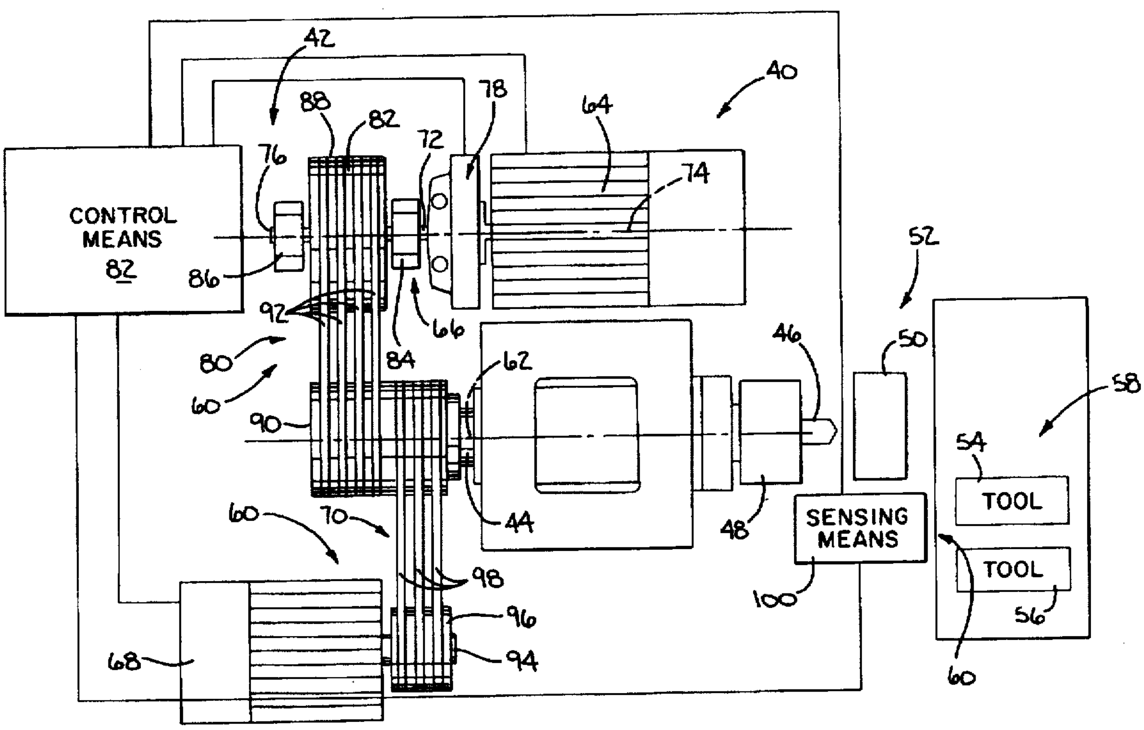
Primary Examiner—William R. Briggs
Attorney, Agent, or Firm—Wood, Phillips, VanSanten, Clark & Mortimer

[57] **ABSTRACT**

A machine tool assembly having a rotatable element for driving a tool to operate on a workpiece and structure for driving the rotatable element in rotation. The driving structure has a first power source and first structure cooperating between the first power source and the rotatable tool driving element for selectively a) allowing the first power source to be operated at one speed to drive the rotatable tool driving element at a first operating speed with the machine tool assembly in a first state and b) allowing the power source to be operated at the one speed without rotating the rotatable tool driving element at the first operating speed with the machine tool assembly in a second state. Structure is provided for changing the machine tool assembly from one of its first and second states to the other of its first and second states.

19 Claims, 2 Drawing Sheets



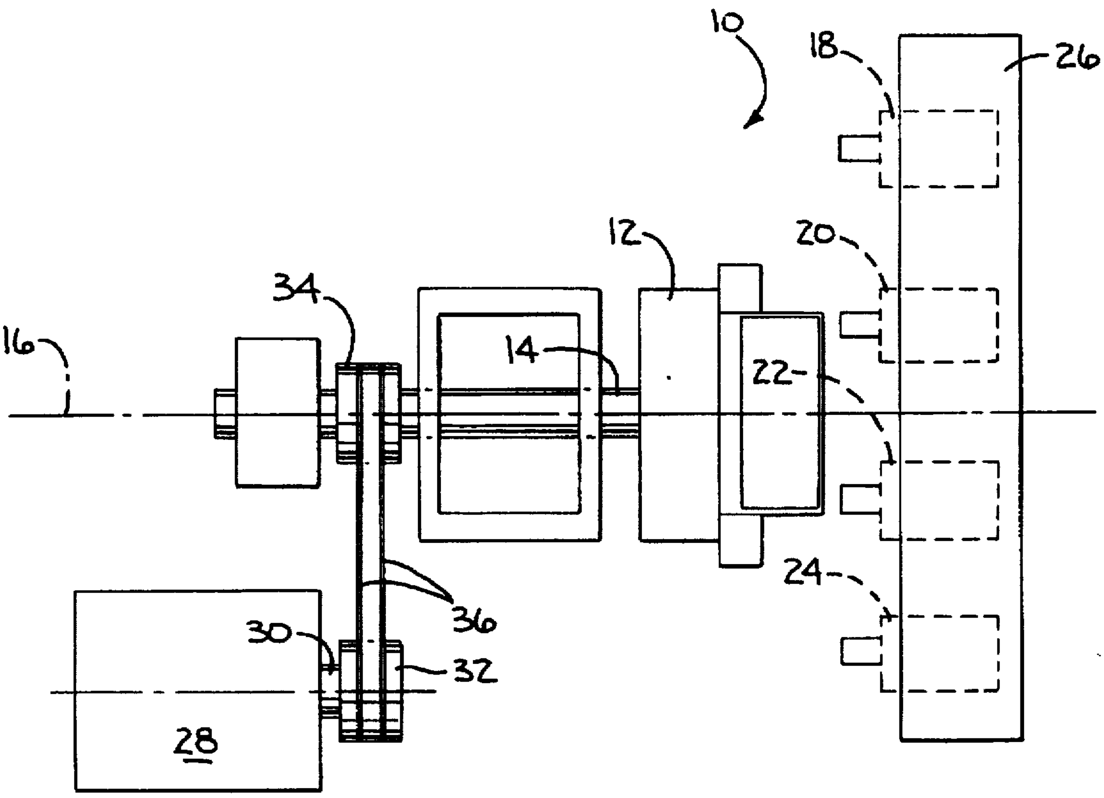


FIG. 1
(PRIOR ART)

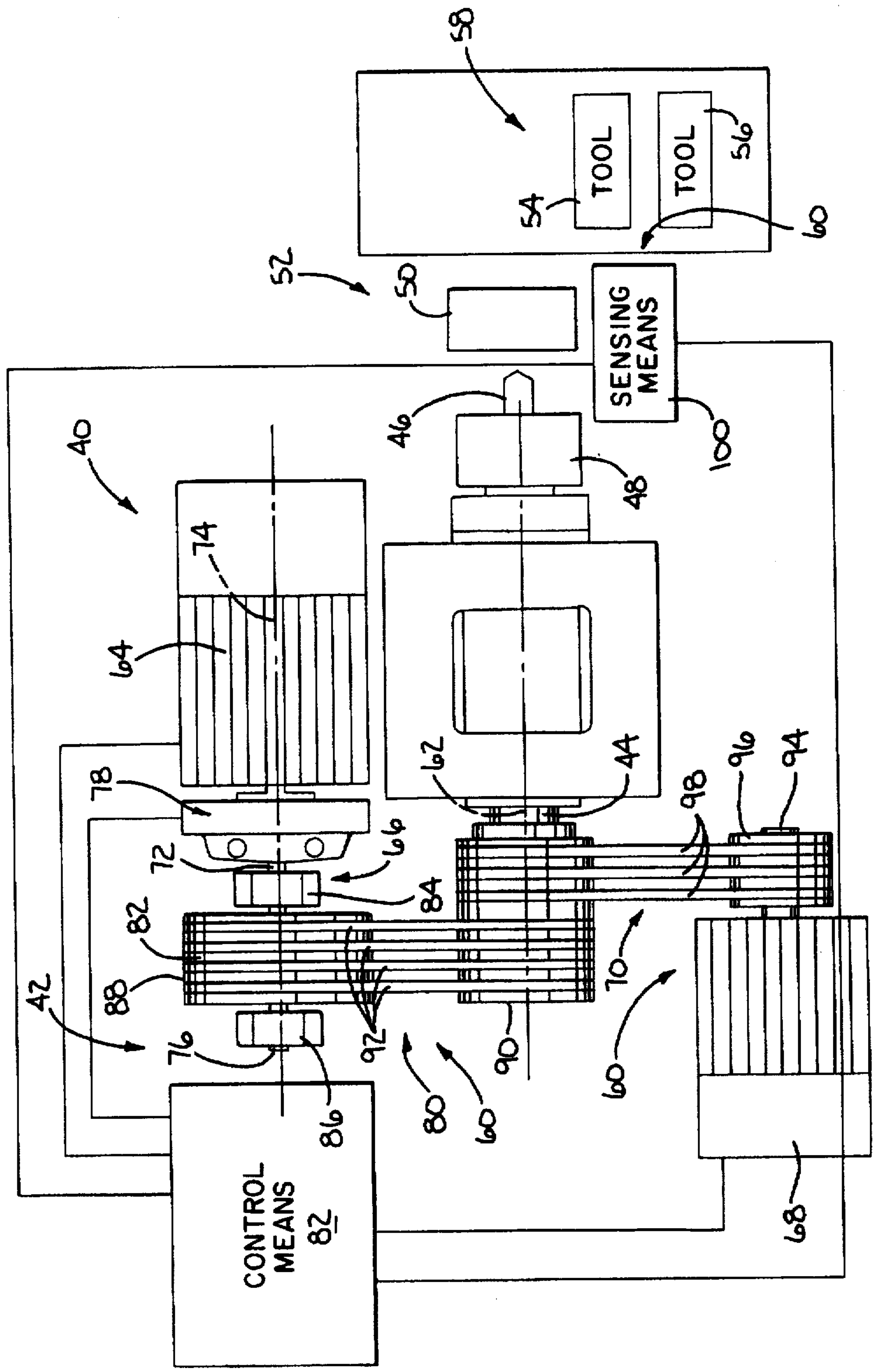


FIG. 2

MACHINE TOOL ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to machine tools of the type having a rotatable spindle that carries a working tool and, more particularly, to a machine tool assembly that can be used to rapidly bring the machine tool spindle up to a predetermined operating speed.

2. Background Art

Machine tools are commonly designed with a rotary spindle with a chuck thereon to releasably hold a working tool. The spindle is driven by a vector motor, typically through one or more endless power transmission belts.

The vector motor is energized with the spindle and chuck initially at rest. On a typical numerically controlled lathe, it will take 3–5 seconds to bring the spindle and chuck up to an operating speed of 2,000 rpm. If a tooling/cutting operation is performed for 10 seconds, the total cycle time from startup to completion is 15 seconds. Reduction in the startup time can significantly reduce the total cycle time. For example, if the startup time could be reduced to one second, the total cycle time would be reduced by approximately 27%. In ongoing machining operations, this time reduction represents a significant economic advantage. Consequently, designers of machine tools strive to minimize this startup time.

It is known to increase the power output of the vector motor to effect a reduction in the startup time. To accomplish this, the vector motor, as well as an amplifier therefor, must be upscaled. The result is generally a more expensive overall system, assuming the other components remain the same.

Additionally, the higher output motor is more expensive to operate and is particularly inefficient when used in light machining operations.

SUMMARY OF THE INVENTION

In one form of the invention, a machine tool assembly is provided having a rotatable element for driving a tool to operate on a workpiece and structure for driving the rotatable element in rotation. The driving structure has a first power source and first structure cooperating between the first power source and the rotatable tool driving element for selectively a) allowing the first power source to be operated at one speed to drive the rotatable tool driving element at a first operating speed with the machine tool assembly in a first state and b) allowing the power source to be operated at the one speed without rotating the rotatable tool driving element at the first operating speed with the machine tool assembly in a second state. Structure is provided for changing the machine tool assembly from one of its first and second states to the other of its first and second states.

The driving structure may include a second power source and second structure cooperating between the second power source and the rotatable tool driving element for driving the rotatable tool driving element at a second operating speed with the machine tool assembly in at least one of its first and second states.

The first and second power sources may have different power output capacities.

The output from the two power sources can be combined for heavy machining operations. At the same time, one power source could be operated to the exclusion of the other. Consequently, the amount of driving power can be appropriately selected depending upon the machining operation to be performed.

Aside from the flexibility and operational efficiency that this system affords, it is generally less expensive to construct than is a machine with a single power source with a comparable power output.

The first cooperating structure may include a clutch assembly having engaged and disengaged states such that the clutch assembly is in the engaged state with the machine tool assembly in its first state and the clutch assembly is in its disengaged state with the machine tool assembly in its second state.

The driving structure may include a motor with a rotary shaft. The first cooperating structure may include a pulley on the rotary shaft and at least one power transmission belt for transmitting power from the pulley to the rotatable tool driving element. The first cooperating structure may selectively a) allow the first power source to be operated at the one speed without rotating the pulley and b) allow the first power source to be operated at the one speed to drive the pulley.

A fly wheel may be provided on the rotary shaft. The fly wheel provides additional momentum which thereby accounts for rapid velocity transfer between the rotary shaft on the first motor and the rotatable tool driving element.

The invention further contemplates the combination of the machine tool assembly with a working tool for operating on a workpiece, with structure cooperating between the working tool and rotatable tool driving element for rotating the working tool as an incident of the rotatable tool driving element being rotated. Control structure can be provided for operating the driving structure, with the control structure including structure for sensing the location of a workpiece in an operating position at a work station and for producing a signal indicative of a workpiece being in that position. The control structure includes structure responsive to the signal from the sensing structure for changing the machine tool from its second state into its first state.

The control structure may include structure responsive to the signal from the sensing structure for operating the second power source.

The rotatable tool driving element may be a spindle having a chuck for receiving a working tool.

The control structure may include structure for generating another signal indicative of a work piece at least one of a) moving into an operating position, and b) moving out of an operating position and structure responsive to the another signal for changing the machine tool from its first state into its second state.

The second power source has an operating state and a stopped state, with the control structure including structure responsive to the another signal for changing the second power source from its operating state to its stopped state.

In another form of the invention, a machine tool is provided having a rotatable element for driving a tool to operate on a workpiece and structure for driving the rotatable element in rotation. The driving structure has a first power source, structure cooperating between the first power source and the rotatable tool driving element for driving the rotatable tool driving element through the first power source at a first operating speed, a second power source, and second structure cooperating between the second power source and the rotatable tool driving element for driving the rotatable tool driving element through the second power source at a second operating speed. The first cooperating structure includes structure for selectively placing the machine tool assembly in a) a first state wherein the first power source operating at one speed drives the rotatable tool driving

element at a first operating speed and b) a second state wherein the rotatable tool driving element is undriven by the first power source with the first power source operating at the one speed. Control structure is provided for selectively c) causing operation of the first power source at the one speed without causing operation of the second power source with the machine tool assembly in the second state and d) causing operation of both the first and second power sources with the machine tool assembly in the first state.

The rotatable tool driving element may be a rotatable shaft and the first and second cooperating structures each include first and second endless power transmission elements driven one each by the first and second power sources and each operatively connected to the rotatable shaft.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a prior art machine tool assembly; and

FIG. 2 is a plan view of a machine tool assembly according to the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

In FIG. 1, a prior art machine tool assembly is shown at **10**. The machine tool assembly **10** is part of a machine tool system that is used to perform any of a number of different machining operations on a workpiece. The machining operations are performed utilizing a chuck **12** that is carried on a spindle **14**, with the chuck **12** and spindle **14** being rotatable about an axis **16**. The chuck **12**, which may be part of a lathe, a milling machine, or the like, rotates any of a number of different cutting tools **18**, **20**, **22**, **24**. The cutting tools **18**, **20**, **22**, **24** are in this particular assembly shown to be carried on a slide **26**. The tools can be either manually or automatically a) placed into operative position in the chuck **12** and removed from the operative position in the chuck **12**. The particular mechanism for accomplishing this is peripheral to the present invention.

The spindle **14** and chuck **12** are driven in rotation about the axis **16** by a variable speed vector motor **28**. The motor **28** has a rotatable shaft **30** with a pulley **32** at its distal end. The pulley **32** is aligned axially of the spindle with another pulley **34** carried by, and rotatable with, the spindle **14**. Two endless power transmission elements **36** are trained around the pulleys **32**, **34** and transmit power from the motor **28** to the spindle **14**.

Since the spindle **14** and chuck **12** are driven solely by the motor **28**, the motor **28** must have the capacity to drive the chuck **12** at the desired operating speed and with sufficient power to carry out the heaviest anticipated machining operations. Regardless of the power output capacity for the motor **28**, there is a significant time lag that occurs in bringing the motor **28** up to speed from a stopped state. There is a further time lag in transmitting power between the pulleys **32**, **34**, by reason of the non-rigid interconnection therebetween. Accordingly, with the motor **28** stopped and the spindle **14** and chuck **12** at rest, a significant startup time is inherent in the assembly **10**, regardless of the power output of the motor **28**.

A machine tool, according to the present invention, is shown at **40** in FIG. **2**. The machine tool assembly **40** is part of an overall system at **42**, which may be a single station or multi-station machine tool system.

The machine tool assembly **40** has a rotatable spindle **44** for driving a tool, in this case a drill bit **46**, which is releasably carried in a chuck **48** at the end of the spindle **44**.

The machine tool assembly could be part of a lathe, or other type of machine tool using a rotatable spindle.

The spindle **44** is driven to cause the tool **46** to perform a desired operation on a workpiece **50** supported at a work station **52**.

The tool **46** can be used to perform multiple operations on each individual workpiece **50**. Alternatively, workpieces **50** can be serially shuttled into working/operating position, as shown for the workpiece **50**, at the work station **52**.

Additional machining operations can be performed by tools **54**, **56**, carried on a gang tool slide **58**. The individual tools **54**, **56** can be manually placed in, and removed from, the chuck **48**. Alternatively, systems well known to those skilled in the art are in existence which automatically effect interchange of the tools. However, again this structure is peripheral to the inventive concept.

Means **60** is provided for driving the spindle **44** in rotation about its axis **62**. The means **60** includes a first power source/motor **64** with first means at **66** cooperating between the motor **64** and spindle **44** for transmitting power from the motor **64** as a rotary drive force to the spindle **44**.

The means **60** includes a second power source/motor with means at **70** cooperating between the motor **68** and spindle **44** for causing the motor **68** to drive the spindle **44** in rotation about its axis **62**.

The motor **64** is preferably a 20–30 h.p. general purpose inverter motor. The motor **64** has a two-part shaft **72** with first and second axially spaced parts **74**, **76**, respectively, operatively connected through a clutch mechanism at **78**. The clutch mechanism **78**, which is also part of the means **66**, has engaged and disengaged states. In the disengaged state, the motor **64** can be operated without transmitting a rotative force to the spindle **44**. In the engaged state, power from the motor is positively transmitted through the shaft parts **74**, **76** and through a belt and pulley arrangement at **80** to the spindle **44**.

The clutch mechanism **78** is changed between engaged and disengaged positions by a control means **82**. The clutch mechanism **78** may be an automotive-type clutch. The clutch currently being used on the Toyota Corolla model automobile would adequately perform the function described herein.

The shaft part **76** carries two axially spaced fly wheels **84**, **86** and a pulley **88** therebetween. The pulley **88** is axially aligned with a pulley **90** on the spindle **44**. A plurality of axially spaced belts **92** are trained around the pulleys **88**, **90** and transfer power from the pulley **88**, driven by the motor **64**, to the pulley **90**, and in turn the spindle **44** on which it is mounted.

The motor **68**, which is preferably a 10 h.p. vector motor, has a rotary shaft **94** that carries a pulley **96**. The pulley **90** has a sufficient axial extent to align with the pulley **96** to allow, in this case, three axially spaced, endless power transmission belts **98** to be trained around the pulleys **90**, **96**, to allow power transmission from the pulley **96** to the pulley **90**, and in turn to the spindle **44** which carries the pulley **90**.

The control means **82** is operatively connected to the motors **64**, **68**, the clutch **78**, and to a means at **100** for sensing the position of a workpiece **50** at the work station **52**.

A typical operation of the machine tool assembly **40** will now be described. Initially, the machine tool assembly **40** is in a state wherein the clutch **78** is disengaged. The control means **82** causes the motor **64** to be powered until it reaches its normal operating speed.

With a tool **46** in the chuck **48** and a workpiece **50** in an operating position at the work station **52**, a sensing means

100 produces a "completion of part loading" signal to the control means **82** which gives a "spindle start" command that causes the motor **68** to be started and at the same time causes the clutch **78** to be placed in its engaged state. Whereas use of the motor **68** alone would cause a significant time to pass between initial startup and the realization of the operating speed for the spindle **44**, the pre-started motor **64**, with the clutch **78** engaged, rapidly causes the spindle **44** to be brought up to a programmed operating speed.

The sensing means **100** may produce another signal indicative of a workpiece moving into and out of an operating position at the work station **52**. This signal causes the clutch mechanism **78** to remain disengaged, the motor **64** to be brought up to a programmed speed, and the motor **68** to be stopped.

To further minimize this response time, fly wheels **84**, **86** are provided on the shaft part **76** to produce additional momentum which is transferred to the pulley **90** and associated spindle **44**.

With this arrangement, it can be seen that the spindle **44** can be rapidly brought up to speed. At the same time, the system benefits from the combined power of the motors **64**, **68**. By placing the clutch **78** in a disengaged state, the smaller motor **68** can be operated alone with the pulley **98** idling. This results in an energy savings.

The resulting system has flexibility from a power standpoint and also can, in most cases, be constructed more cheaply than the same system with a single 40 h.p. motor.

The foregoing disclosure of specific embodiments is intended to be illustrative of the broad concepts comprehended by the invention.

We claim:

1. A machine tool assembly comprising:

a rotatable element for driving a tool to operate on a workpiece;

means for driving the rotatable element in rotation,

said driving means comprising a first power source and first means cooperating between the first power source and the rotatable tool driving element for selectively a) allowing the first power source to be operated at one speed to drive the rotatable tool driving element at a first operating speed with the machine tool assembly in a first state and b) allowing the first power source to be operated at the one speed without rotating the rotatable tool driving element at the first operating speed with the machine tool assembly in a second state,

said driving means further comprising a second power source and second means cooperating between the second power source and the rotatable tool driving element for driving the rotatable tool driving element at a second operating speed both with the machine tool assembly in the first state and the machine tool in the second state; and

means for changing the machine tool assembly from one of its first and second states to the other of its first and second states.

2. A machine tool assembly comprising:

a rotatable element for driving a tool to operate on a workpiece;

means for driving the rotatable element in rotation,

said driving means comprising a first power source, first means cooperating between the first power source and the rotatable tool driving element for driving the rotatable tool driving element through the first power source at a first operating speed, a second power source, and

second means cooperating between the second power source and rotatable driving element for driving the rotatable tool driving element through the second power source at a second operating speed,

said first cooperating means including means for selectively placing the machine tool assembly in a) a first state wherein the first power source operating at one speed drives the rotatable tool driving element at a first operating speed and b) a second state wherein the rotatable tool driving element is undriven by the first power source with the first power source operating at the one speed; and

control means for selectively c) causing operation of the first power source at the one speed without causing operation of the second power source with the machine tool assembly in the second state and d) causing operation of both the first and second power sources with the machine tool assembly in the first state.

3. The machine tool assembly of claim **1** wherein the first and second power sources comprise motors having different power output capacities.

4. The machine tool assembly of claim **1** wherein the first cooperating means includes a clutch assembly having engaged and disengaged states and the clutch assembly is in the engaged state with the machine tool assembly is in its first state and the clutch assembly is in its disengaged state with the machine tool assembly is in its second state.

5. A machine tool assembly comprising:

a rotatable element for driving a tool to operate on a workpiece;

means for driving the rotatable element in rotation,

said driving means comprising a first power source and first means cooperating between the first power source and the rotatable tool driving element for selectively a) allowing the first power source to be operated at one speed to drive the rotatable tool driving element at a first operating speed with the machine tool assembly in a first state and b) allowing the power source to be operated at the one speed without rotating the rotatable tool driving element at the first operating speed with the machine tool assembly in a second state,

the driving means further comprising a motor with a rotary shaft, and the first cooperating means comprising a pulley on the rotary shaft, at least one power transmission belt for transmitting power from the pulley to the rotatable tool driving element, and means for selectively a) allowing the first power source to be operated at the one speed without rotating the pulley and b) allowing the first power source to be operated at the one speed to drive the pulley; and

means for changing the machine tool assembly from one of its first and second states to the other of its first and second states.

6. The machine tool assembly of claim **5** wherein there is a flywheel on the rotary shaft.

7. A machine tool assembly comprising:

a working tool for operating on a workpiece;

a rotatable element for driving the working tool to operate on a workpiece;

means cooperating between the working tool and the rotatable tool driving element for rotating the working tool as an incident of the rotatable tool driving element being rotated;

means for driving the rotatable element in rotation,

said driving means comprising a first power source and first means cooperating between the first power source

and the rotatable tool driving element for selectively a) allowing the first power source to be operated at one speed to drive the rotatable tool driving element at a first operating speed with the machine tool assembly in a first state and b) allowing the power source to be operated at the one speed without rotating the rotatable tool driving element at the first operating speed with the machine tool assembly in a second state;

means for changing the machine tool assembly from one of its first and second states to the other of its first and second states; and

control means for operating the driving means, said control means including means for sensing the location of a workpiece in an operating position at a work station and for producing a signal indicative of a workpiece being in an operating position at a work station, said control means including means responsive to the signal from the sensing means for changing the machine tool from its second state into its first state.

8. The machine tool assembly of claim **7** wherein the driving means includes a second power source and second means cooperating between the second power source and the rotatable tool driving element for driving the rotatable tool driving element at a second operating speed with the machine tool assembly in at least one of the first and second states and the control means includes means responsive to the signal from the sensing means for operating the second power source.

9. The machine tool assembly of claim **1** wherein the rotatable tool driving element comprises a spindle having a chuck for receiving a working tool.

10. The machine tool assembly of claim **8** wherein the control means includes means for generating another signal indicative of a workpiece at least one of a) moving into an operating position and b) moving out of an operating position and means responsive to the another signal for changing the machine tool from its first state into its second state.

11. The machine tool assembly of claim **10** wherein the second power source has an operating state and a stopped state and the control means includes means responsive to the another signal for changing the second power source from its operating state to its stopped state.

12. The machine tool assembly according to claim **2** wherein the rotatable tool driving element comprises a spindle with a chuck for a working tool.

13. The machine tool assembly according to claim **2** wherein the first and second power sources comprise motors having different power output capacities.

14. The machine tool assembly according to claim **13** wherein the control means includes means for sensing the location of a workpiece in an operating position at a work station and for producing a signal indicative of a workpiece being in an operating position at a work station, said control means including means responsive to the signal from the sensing means for causing the machine tool assembly to change from the second state into the first state.

15. The machine tool assembly according to claim **14** wherein the control means includes means responsive to the signal from the sensing means for operating the second power source.

16. The machine tool assembly according to claim **14** wherein the means for causing the machine tool assembly to change from the second state into the first state comprises means for causing the machine tool assembly to change from the second state into the first state with the first power source operating at a predetermined speed.

17. The machine tool assembly according to claim **2** wherein the means for selectively placing the machine tool assembly in the first state comprises a clutch mechanism.

18. The machine tool assembly according to claim **2** wherein the rotatable tool driving element comprises a rotatable shaft and the first and second cooperating means each include first and second endless power transmission elements driven one each by the first and second power sources and each operatively connected to the rotatable shaft.

19. The machine tool assembly according to claim **2** wherein the first power source comprises a motor with a rotary shaft and there is a flywheel on the rotary shaft.

* * * * *

US005758554A

United States Patent [19]
Miyano

[11] Patent Number: 5,758,554
[45] Date of Patent: Jun. 2, 1998

[54] **MACHINE TOOL AND METHOD FOR MACHINING A LONG-SHAFTED WORKPIECE**

[76] Inventor: **Toshiharu Tom Miyano**, c/o Miyano Machinery USA Inc., 940 N. Central Ave., Wood Dale, Ill. 60191

[21] Appl. No.: **759,467**

[22] Filed: **Dec. 5, 1996**

[51] **Int. Cl.**^{6} **B23B 1/00**
[52] **U.S. Cl.** **82/1.11**; 82/121; 82/129
[58] **Field of Search** 82/1.11, 121, 127, 82/124, 129, 142

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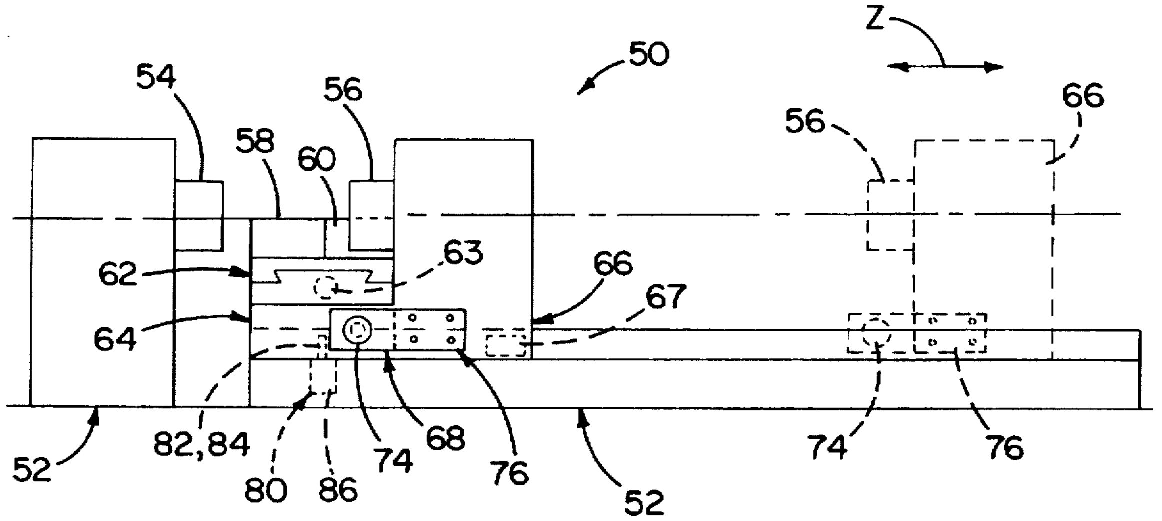
Primary Examiner—A. L. Pitts
Assistant Examiner—Mark Williams
Attorney, Agent, or Firm—Wood, Phillips, Van Santen, Clark & Mortimer

[57] **ABSTRACT**

A machine tool for machining a workpiece having a long shaft section. The machine tool includes a frame, a tool holder on the frame for holding the cutting tool to machine a workpiece, a first slide assembly and a first servo motor on the frame for translating the tool holder along a first axis relative to the frame, a second slide assembly on the frame for mounting the tool holder for translation along a second axis relative to the frame, a first workpiece holder on the frame for holding the workpiece to be machined by a cutting tool held in the tool holder, a second workpiece holder on the frame for holding a workpiece to be machined by a cutting tool held in the tool holder, a third slide assembly and a second servo motor for translating the second workpiece holder along the second axis, and structure for selectively connecting the tool holder to the second workpiece holder for translation of the tool holder by the third slide assembly and the second servo motor along the second axis.

17 Claims, 7 Drawing Sheets



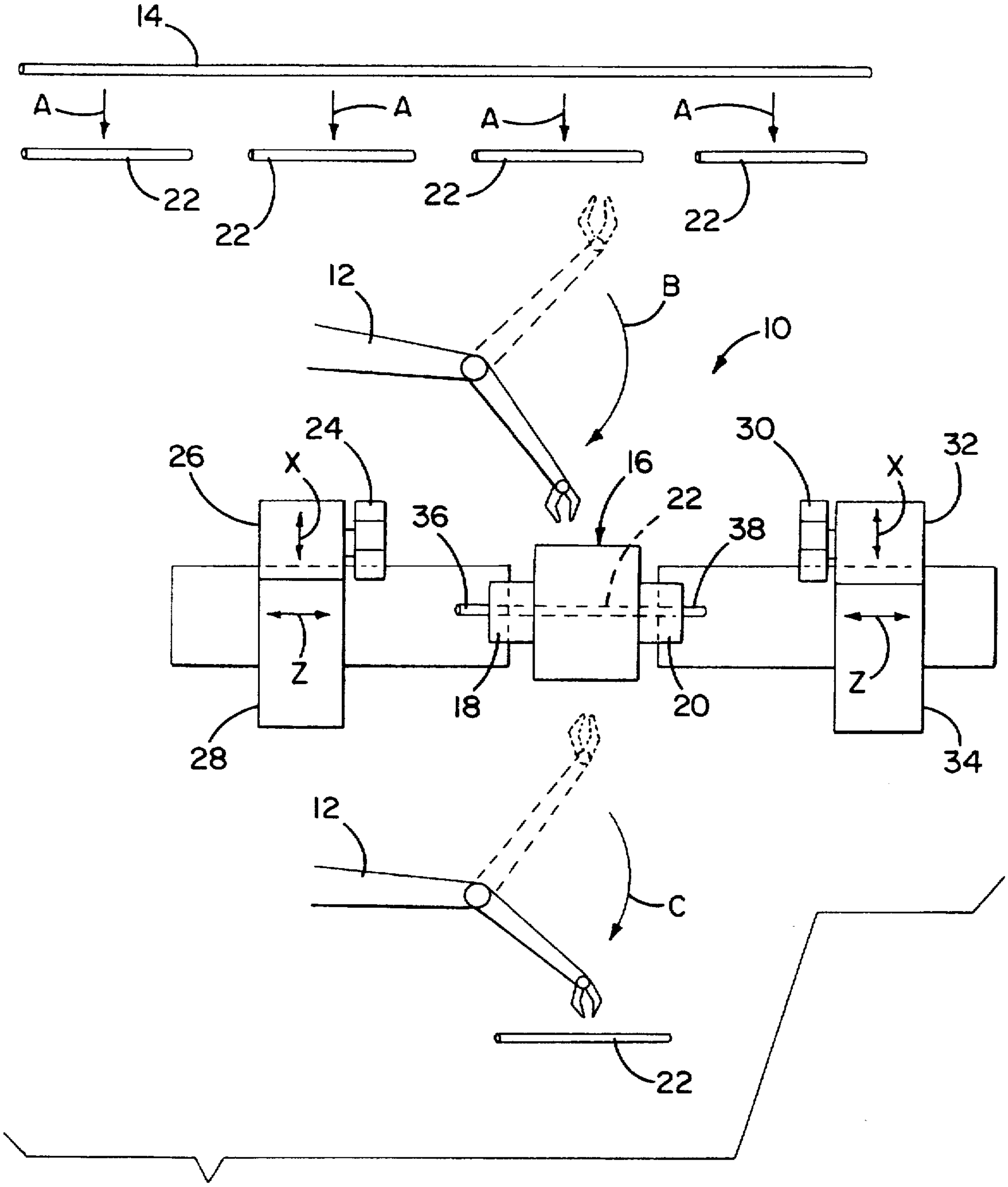
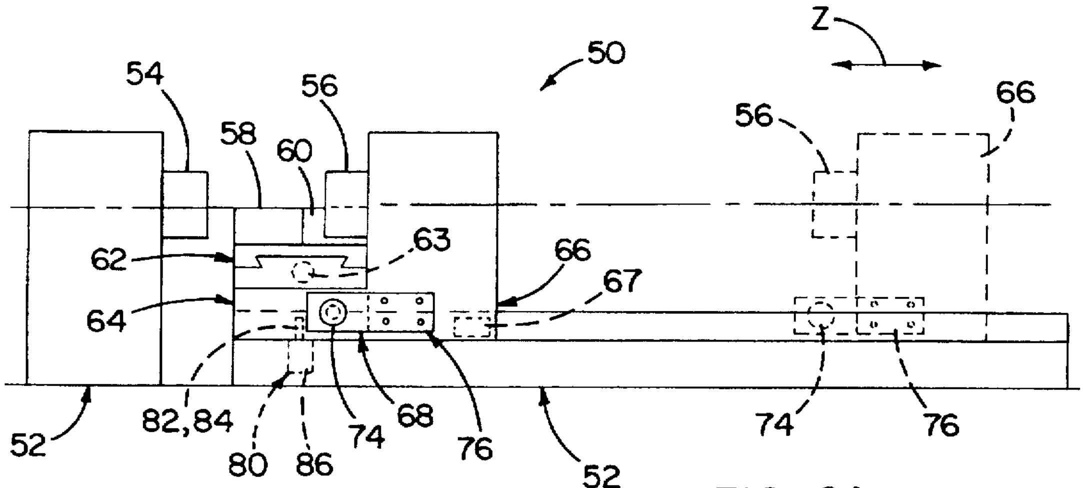


FIG. 1
(PRIOR ART)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58
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67
64
52
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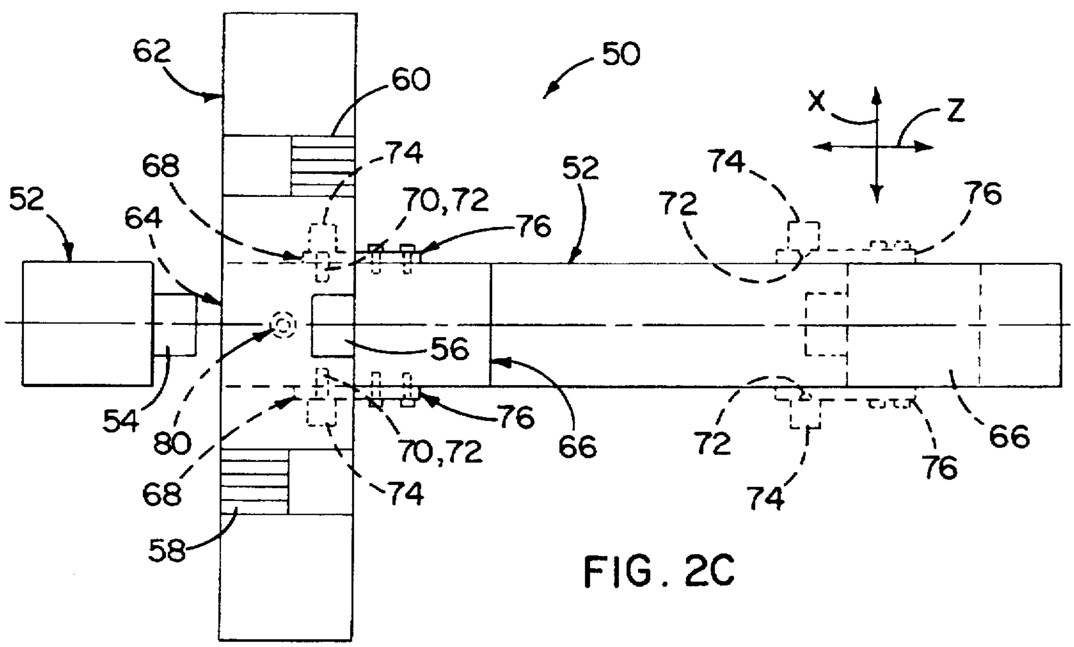
76
52
74
76

FIG. 2A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X
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74
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76
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72
66
76
74
74

FIG. 2C

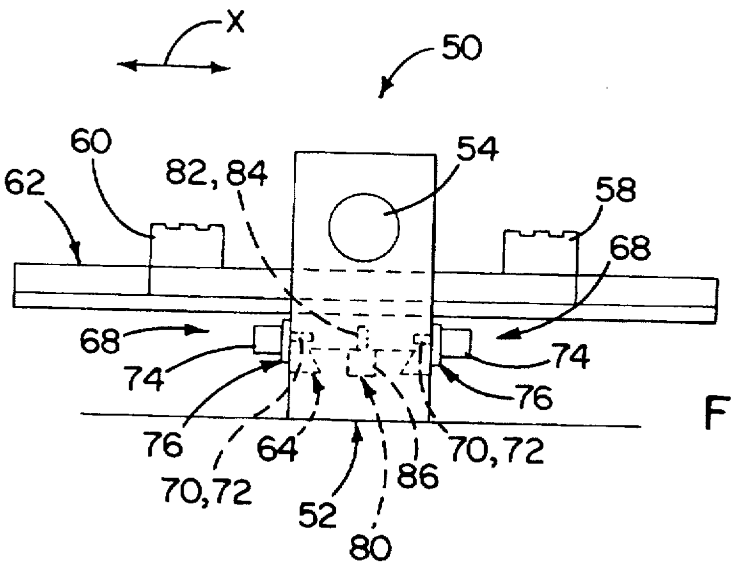


FIG. 2B

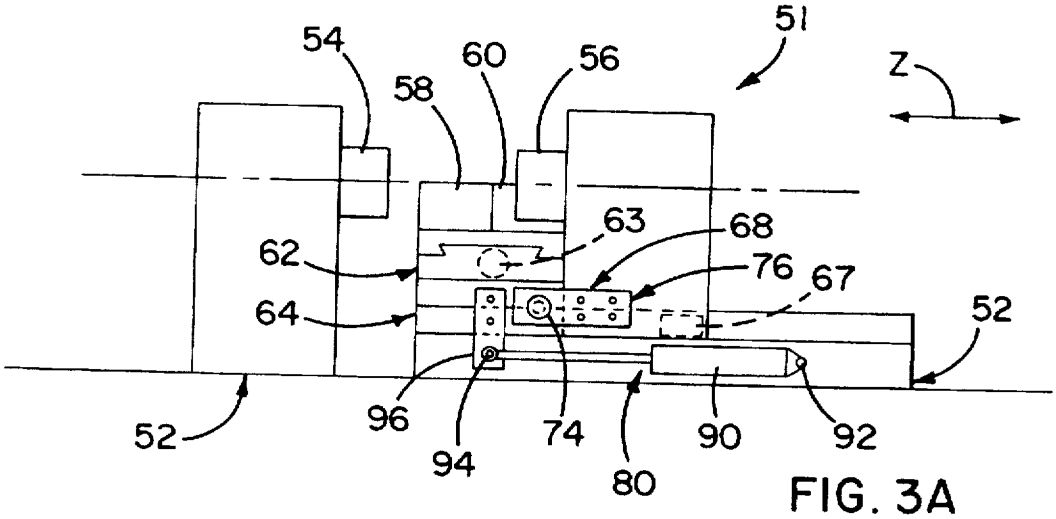


FIG. 3A

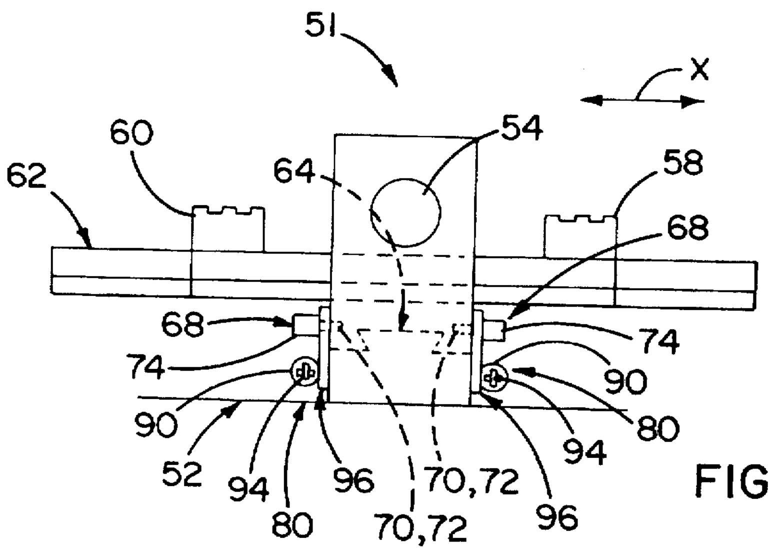
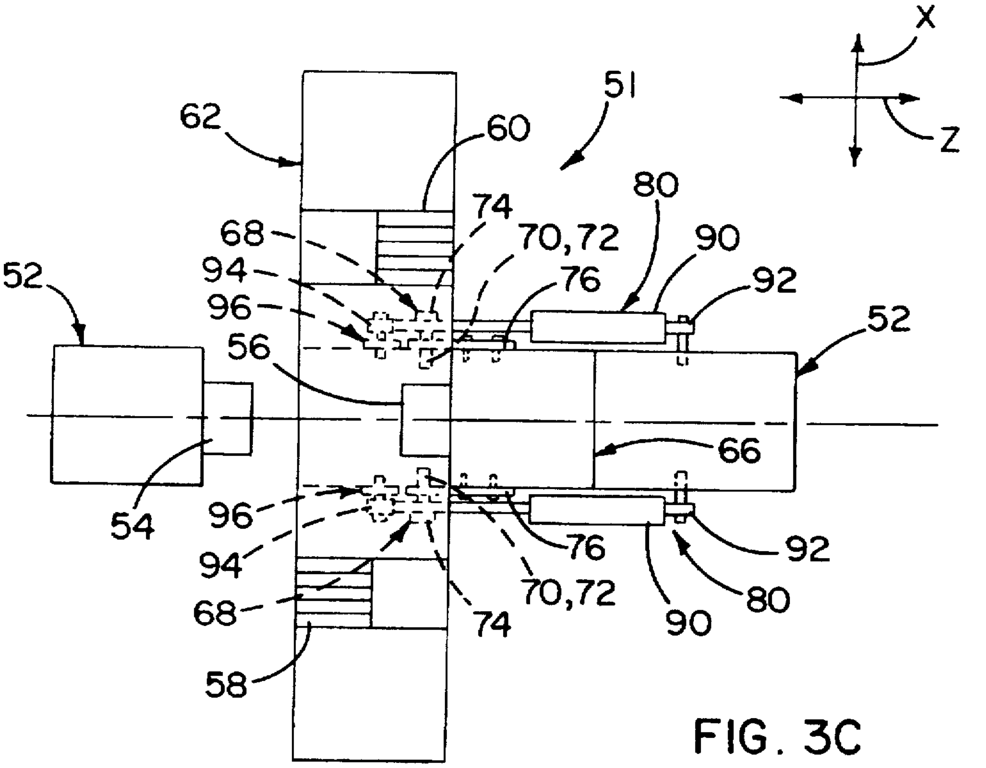


FIG. 3B



X
Z
51
62
60
80
74
70,72
90
68
94
76
92
52
96
56
52
66
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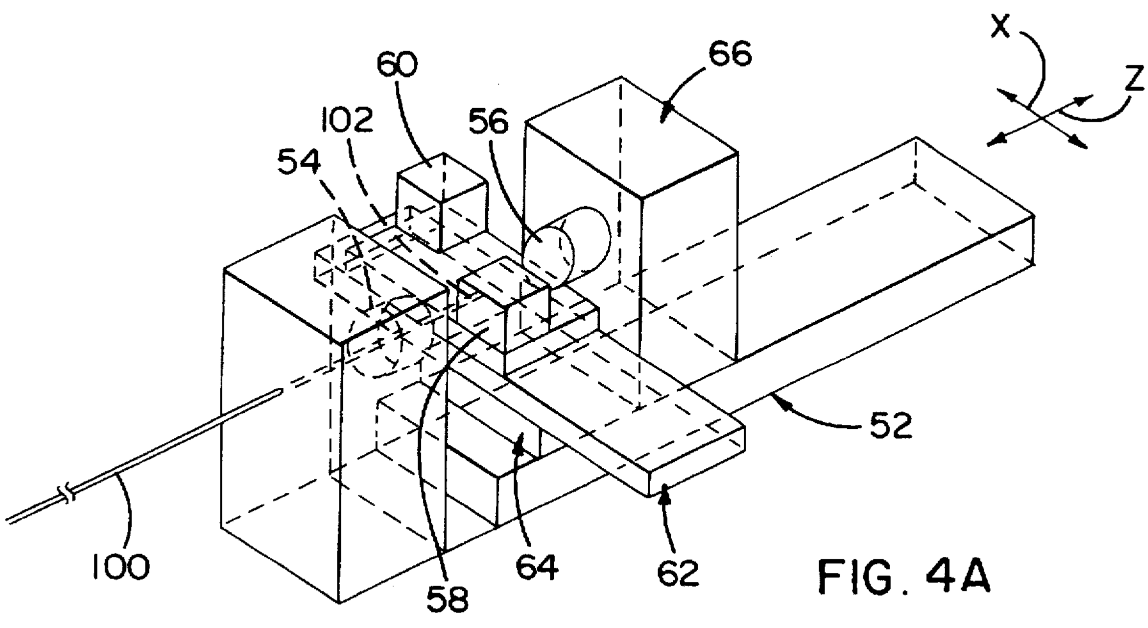
96
76
92
94
70,72
80
68
74
90
58

FIG. 3C



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56
54
52
100
64
62
58

FIG. 4A

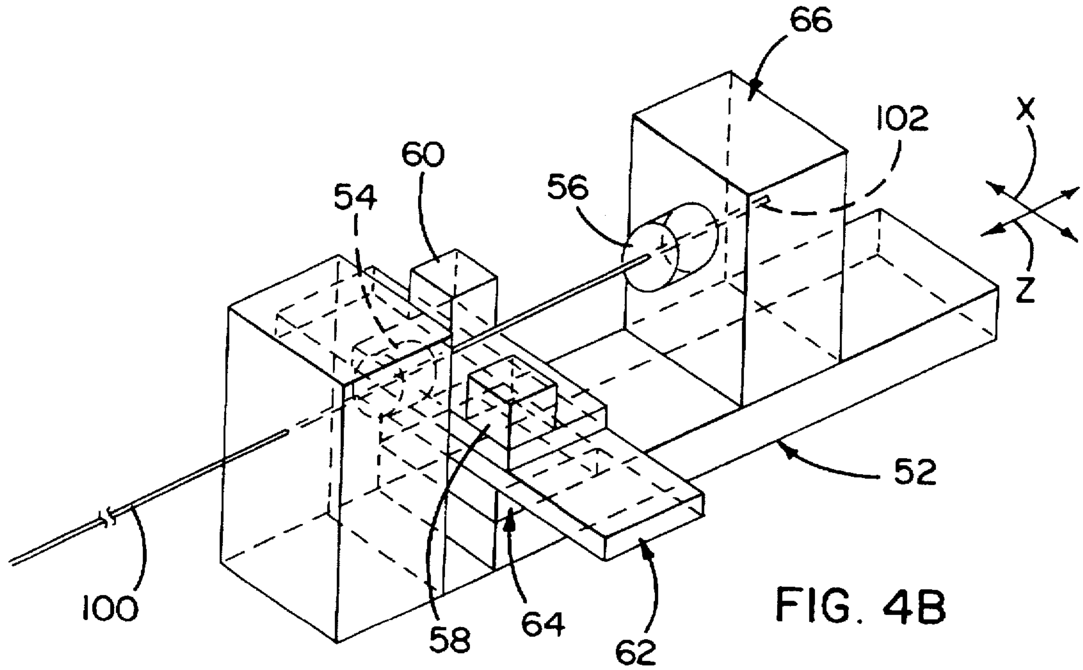
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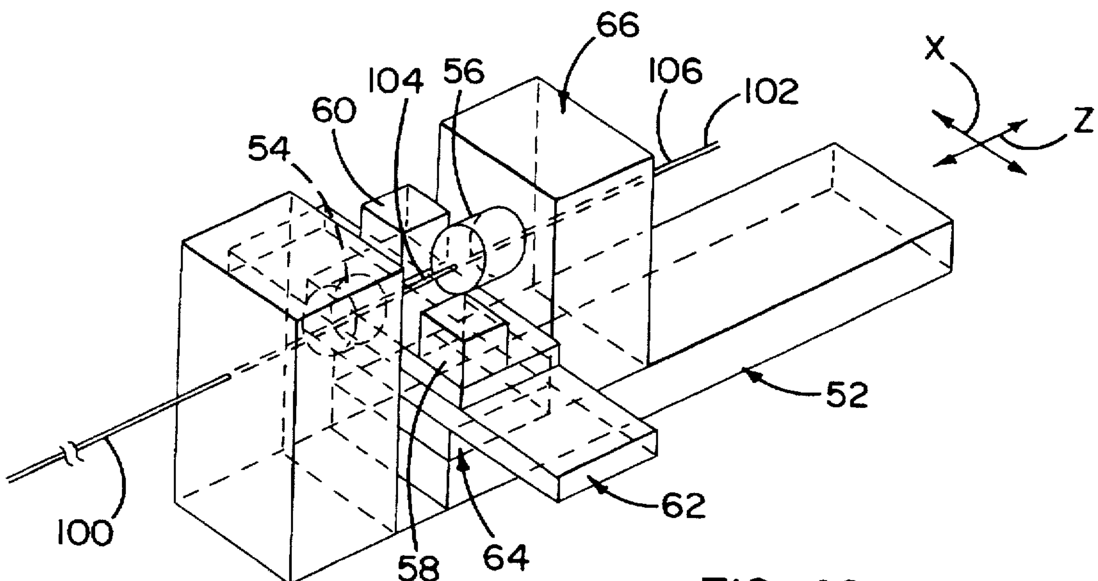
FIG. 4B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Z
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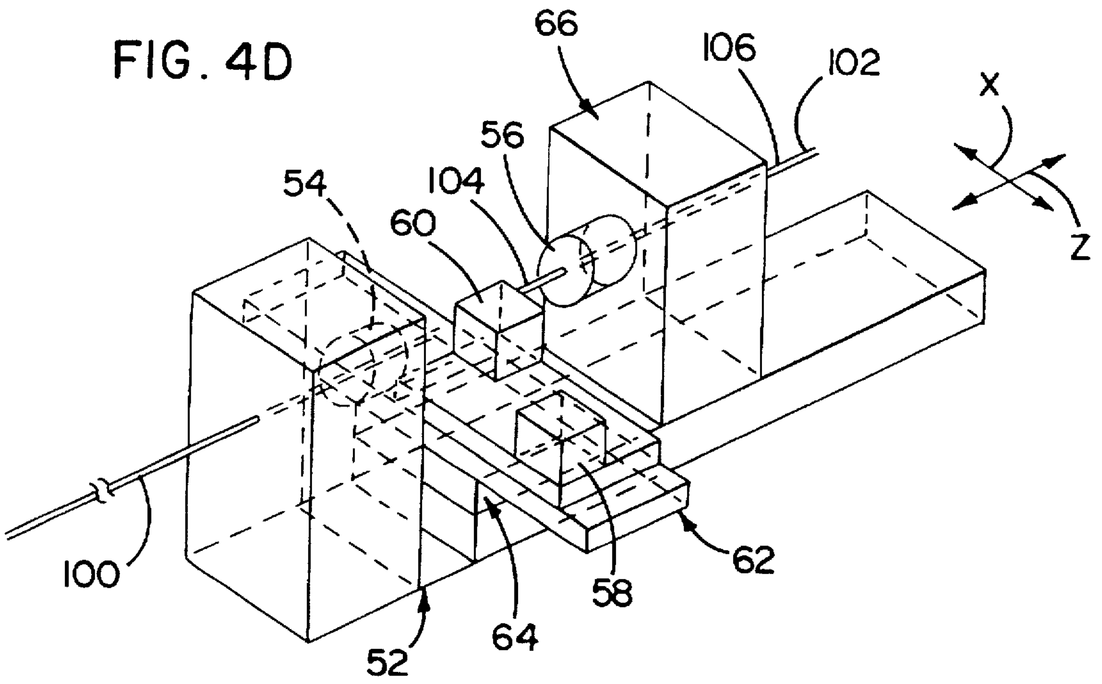
52
62
100
58
64

FIG. 4C

FIG. 4D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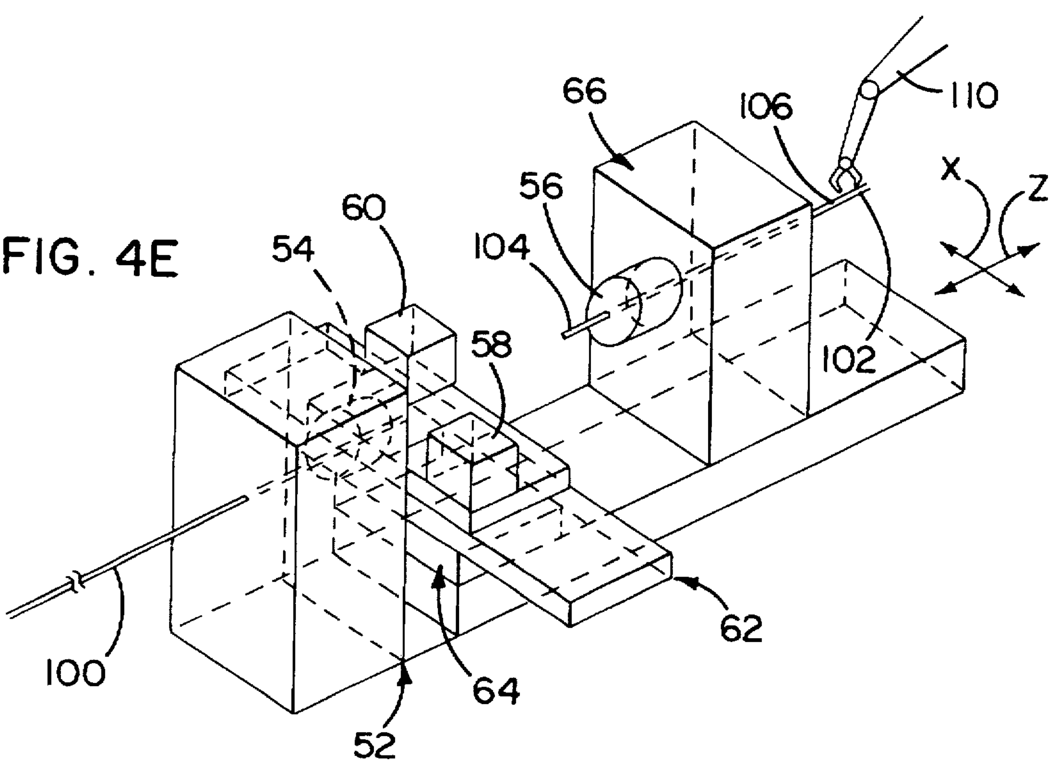
52

FIG. 4E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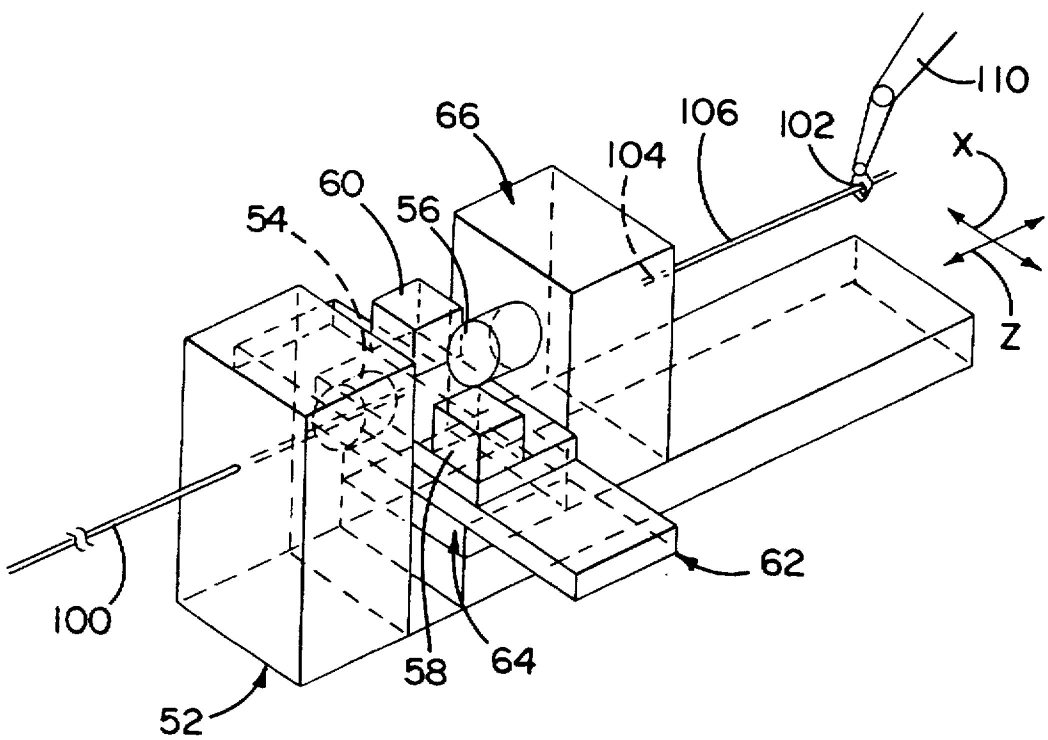

FIG. 4F

MACHINE TOOL AND METHOD FOR MACHINING A LONG-SHAFTED WORKPIECE

FIELD OF THE INVENTION

This invention relates to machine tools and, more particularly, to machine tools for machining a workpiece having a long shaft.

BACKGROUND OF THE INVENTION

Machine tools for machining workpiece having a long shaft section, such as a torsion bar or a steering linkage, are known in the art. Typically, such machine tools are NC turning lathes having four or more axes. More specifically, such lathes normally have a centrally-located workpiece spindle rotatably mounting a pair of chucks on opposite sides of the spindle, with each chuck having a dedicated X axis slide assembly and Z axis slide assembly for translating a tool holder relative to a workpiece held in the chuck. Each of the four slide assemblies has a dedicated servo motor for translating the slide along its axis.

These lathes typically require at least four steps to make a single long-shafted workpiece. First, a separate machine tool is used to cut a workpiece from a length of material bar stock. Second, the workpiece is mounted in the centrally-located spindle, with each end of the workpiece extending from one of the chucks. Third, each end of the workpiece is machined by a cutting tool manipulated by the X and Z axes slide assemblies dedicated to each chuck. Fourth, the finished workpiece is removed from the NC lathe.

Thus, it can be seen that conventional practice requires not only an NC lathe having at least four axes with a dedicated slide assembly and servo motor for each axis, but also a separate machine tool for cutting the initial workpiece to length from a length of material bar stock.

Summary of the Invention

In accordance with the present invention, a machine tool is provided for machining a workpiece having a long shaft section. The machine tool includes a frame, a tool holder on the frame for holding a cutting tool to machine a workpiece, a first slide assembly and a first servo motor on the frame for translating the tool holder along a first axis relative to the frame, a second slide assembly on the frame for mounting the tool holder for translation along a second axis relative to the frame, a first workpiece holder on the frame for holding a workpiece to be machined by a cutting tool held in the tool holder, a second workpiece holder on the frame for holding a workpiece to be machined by a cutting tool held in the tool holder, a third slide assembly and a second servo motor for translating the second workpiece holder along the second axis, and structure for selectively connecting the tool holder to the second workpiece holder for translation of the tool holder by the third slide assembly and the second servo motor along the second axis.

In one form, the first workpiece holder includes a rotatable element for driving the workpiece as it is machined by a cutting tool, and the second workpiece holder

includes a second rotatable element for driving the workpiece as it is machined by a cutting tool. In one form, the tool holder is a turret holding a plurality of cutting tools.

In one form, the structure for selectively connecting the first tool holder to the second workpiece holder includes an aperture in one of the first tool holder, the first slide assembly, and the second slide assembly; a lock pin carried

on one of the second workpiece holder and the third slide assembly; and a servo carried on the one of the tool holder and the third slide assembly for selectively extending the lock pin into engagement with the aperture.

In one form, the machine tool further includes structure on the frame for selectively fixing the second slide assembly to the frame to prevent translation of the first tool holder along the second axis.

In one form, the machine tool further includes a second tool holder for holding the cutting tool to machine a workpiece.

In one form, a machine tool is provided for machining a workpiece having a long shaft section. The machine tool includes a frame, first structure on the frame for mounting a cutting tool for translation along a first axis and a second axis to machine a workpiece, a first workpiece holder on the frame for holding a workpiece to be machined by a cutting tool mounted by the first structure, a second workpiece holder on the frame for holding a workpiece to be machined by a cutting tool mounted by the first structure, second structure on the frame for translating the second workpiece holder along the second axis, and third structure on the frame for selectively connecting the first structure to the second structure for translation of the first structure by the second structure along the second axis.

In accordance with the present invention, a method for machining a workpiece is provided and includes the steps of providing a workpiece, providing a cutting tool holder for holding the cutting tool to machine the workpiece, providing a first workpiece holder, providing a second workpiece holder that is translatable along a first axis, loading the workpiece into the first workpiece holder, connecting the cutting tool holder to the second workpiece holder, and translating the cutting tool holder and the second workpiece holder together along the first axis while the workpiece is held by the first workpiece holder and machined by a cutting tool held in the cutting tool holder.

In one form, the method further includes the steps of loading the workpiece into the second workpiece holder, fixing the cutting tool holder relative to the first axis, disconnecting the cutting tool holder from the second workpiece holder, and translating the second workpiece holder and the workpiece together along the first axis while the workpiece is held by the second workpiece holder and machined by a cutting tool held in the cutting tool holder.

In accordance with the present invention, a method of processing the workpiece is provided and includes the steps of providing a workpiece, providing a first workpiece holder, providing a second workpiece holder that is translatable along a first axis, holding the workpiece with the first workpiece holder while a first processing operation is performed on the workpiece, releasing the workpiece from the workpiece holder so that the workpiece may move relative to the first workpiece holder, loading the workpiece into the second workpiece holder, and drawing a length of the workpiece through the first workpiece holder while the second workpiece holder is translated along the first axis holding the workpiece.

In one form, the method further includes holding the workpiece with the first workpiece holder after the length has been drawn through the first workpiece holder, releasing the workpiece from the second workpiece holder so that the second workpiece holder may move relative to the workpiece, translating the second workpiece holder along the first axis while the workpiece is held by the first workpiece holder so that at least a portion of the length is

translated through the second workpiece holder, and performing a second processing operation on the workpiece holder while the workpiece is held by at least one of the first and second workpiece holders.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic plan view of a conventional machine tool set-up for machining a workpiece having a long shaft section;

FIG. 2A is a diagrammatic front elevation view of a machine tool embodying the present invention;

FIG. 2B is a diagrammatic left side elevation view of the machine tool shown in FIG. 2A;

FIG. 2C is a diagrammatic plan view of the machine tool shown in FIG. 2A;

FIG. 3A is a diagrammatic front elevation view of another machine tool embodying the present invention;

FIG. 3B is a diagrammatic left side elevation view of the machine tool shown in FIG. 3A;

FIG. 3C is a diagrammatic plan view of the machine tool shown in FIG. 3A; and

FIGS. 4A, 4B, 4C, 4D, 4E and 4F are diagrammatic perspective views of a machine tool embodying the present invention and illustrating the steps of a machining process embodying the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A plan view of a conventional machine tool set-up for machining a workpiece having a long shaft section is illustrated in FIG. 1 in the form of a CNC (computer numerical controlled) lathe **10**, a robot arm **12**, and a length of material bar stock **14**. The lathe **10** includes conventional operating components that are well known to those skilled in the art. These operating components include a spindle assembly **16** having a pair of oppositely-projecting chucks **18** and **20** for rotating a workpiece **22**, a first turret **24** for holding a plurality of cutting tools (not shown), a first pair of X and Z axis slide assemblies **26** and **28** for moving the first turret **24** and thereby manipulating a cutting tool held by the turret **24** relative to the workpiece **22** as the workpiece is rotated in the chuck **18**, a second turret **30** for holding a plurality of cutting tools (not shown), and a second set of X and Z axis slide assemblies **32** and **34** for moving the first turret **24** and thereby manipulating a cutting tool held by the turret **30** relative to the workpiece **22** as it is rotated in the chuck **20**. Each of the slide assemblies **26**, **28**, **32** and **34** has a dedicated servo motor **35** for translating the slide assembly along its axis.

In the conventional process, a bar-feeding machine (not shown) feeds a length of material bar stock **14** into a cutting machine (not shown) wherein a plurality of workpieces **22** are cut to length, as illustrated by the lines A in FIG. 1. As they are cut to length, the workpieces **22** are loaded into the lathe **10** by the robot arm **12** or by an operator, as illustrated by line B. After a workpiece **22** is loaded into the lathe **10**, both ends **36** and **38** of the workpiece **22** are machined by the operating components **18**, **24**, **26** and **28**, and **20**, **30**, **32**, and **34**, respectively. After the machining of a workpiece **22** has been completed, the workpiece **22** may be removed from the lathe **10** by the robot arm **12** or by an operator, as illustrated by line C.

Having described a conventional machine tool **10** for machining a workpiece **22** having a long shaft section, the preferred embodiments of the invention will now be described.

The invention is embodied in a machine tool **50** shown in FIGS. 2A, 2B, and 2C and a machine tool **51** shown in FIGS. 3A, 3B, and 3C, with both of the machine tools **50** and **51** illustrated in the form of a CNC lathe. The machine tool **50** includes a frame, shown generally at **52**, a first rotatable element or chuck **54** mounted on the frame for driving a workpiece as it is machined by a cutting tool, a second rotatable element or chuck **56** mounted on the frame for driving a workpiece as it is machined by a cutting tool, a first tool holder **58**, a second tool holder **60**, an X axis slide assembly **62** and a dedicated actuator or servo motor **63** for translating the first and second tool holders **58** and **60** along the X axis relative to the frame **52**, a first Z axis slide assembly **64** for mounting the X axis slide assembly **62** and the tool holders **58** and **60** for translation along the Z axis relative to the frame, and a second Z axis slide assembly **66** and a dedicated actuator or servo motor **67** for translating the chuck **56** along the Z axis relative to the frame. The chucks **54** and **56**, the tool holders **58** and **60**, the slide assemblies **62**, **64** and **66**, and the dedicated actuators or servo motors **63** and **67** are conventional operating components and may be any of the types known to those skilled in the art.

The lathe **50** further includes means, shown generally at **68**, for selectively connecting the second Z axis slide assembly **66** to the first Z axis slide assembly **64**, the X axis slide assembly **62** and its dedicated servo motor, and the tool holders **58** and **60**, so that each follows movement of the other along the Z axis. The connecting means **68** is shown in the form of a pair of apertures **70** in the first Z axis slide assembly **64** and a pair of lock pins **72** mounted on the second Z axis slide assembly **66**. Each of the lock pins **72** is actuated into and out of engagement with the apertures **70** by a servo **74** fixed to the second Z axis slide assembly **66** by a bracket and fastener assembly **76**. The apertures **70** and the lock pins **72** may desirably be any of the self-centering configurations known to those skilled in the art, such as a conical hole and a conical mating pin.

The machine tools **50** and **51** further include means, shown generally at **80** in FIGS. 2A, 2B and 2C and in FIGS. 3A, 3B and 3C on the frame **52** for selectively fixing the first Z axis slide assembly **64** to the frame **52** to prevent translation along the Z axis of the first Z axis slide assembly **64**, the X axis slide assembly **62**, the servo motor **63**, and the tool holders **58** and **60**. In the machine tool **50**, the fixing means **80** is shown in FIGS. 2A–C in the form of an aperture **82** in the first Z axis slide assembly **64** and a lock pin **84** mounted on the frame **52**. A servo **86** mounted on the frame **52** selectively extends the lock pin **84** into and out of engagement with the aperture **82**. In the machine tool **51** shown in FIGS. 3A, 3B and 3C, the fixing means **80** is shown in the form of a pair of hydraulic cylinders **90**, with each of the cylinders **90** having a first gimbaled end **92** fixed to the frame **52** and a second gimbaled end **94** fixed by a bracket and fastener assembly **96** to the first Z axis slide assembly **64**.

The operation of the machine tools **50** and **51** will now be explained with reference to FIGS. 4A, 4B, 4C, 4D, 4E and 4F which illustrate a method embodying the present invention for manufacturing a workpiece having a long shaft section.

As best seen in FIG. 4A, a length of the material bar stock **100** having an end **102** is fed into the first chuck **54** by a conventional bar stock feeding apparatus, as is known in the art. The first and second Z axis slide assemblies **64** and **66** are connected by the connecting means **68** (not shown) with the lock pins **72** extended into the apertures **70** by the servos **74**. In this mode, the servo motor **67** associated with the

second Z slide assembly **66** can translate the first Z axis slide assembly **64** together with the second Z axis slide assembly **66** to position the slide assemblies **64** and **66** along the Z axis. In this manner, a bar stop tool (not shown) held by either of the tool holders **58**,**60** is accurately positioned along the Z axis by the servo motor **67** so that the bar stock **100** is stopped after a desired length of bar stock **100** has been fed through the first chuck **54**, thereby correctly positioning the bar stock **100** in the first chuck **54**.

After correctly positioning the bar stock **100** in the first chuck **54** and tightening the first chuck **54** on the bar stock **100**, the machine tools **50**,**51** machine the first end **102** of the bar stock **100** by rotating the bar stock **100** with the first chuck **54** while machining the end **102** with cutting tools (not shown) that are held by either of tool holders **58**,**60** and translated along the X axis by the X axis slide assembly **62** and the servo motor **63** (not shown) and along the Z axis by the first and second Z axis slide assemblies **64** and **66** and the servo motor **67** (not shown).

As best seen in FIG. 4B, after the end **102** has been completely machined, the X slide assembly **62** is centered and the first chuck **54** is loosened to allow the bar stock **100** to be fed by the bar stock feeding apparatus into engagement with the second chuck **56**. After the bar stock **100** is engaged with the second chuck **56**, the connecting means **68** (not shown) releases the first Z axis slide **64** from the second Z axis slide **66** by withdrawing the lock pin **72** from the aperture **70** with the servos **74**. Additionally, at this time, the fixing means **80** (not shown) fixes the second Z axis slide assembly **64** to the frame **52** by placing the lock pin **84** into engagement with the aperture **82** using the servo **86** or by energizing the hydraulic cylinders **90** to fix the ends **92** and **94** relative to each other. Next, the second Z axis slide assembly **66** and the servo motor **67** pull a desired length of the bar stock **100** through the first chuck **54** by translating the second chuck **56** to the right along the Z axis.

As best seen in FIG. 4C, after the desired length of bar stock **100** is pulled through the first chuck **54**, the first chuck **54** is tightened to hold the bar stock **100** and the second chuck **56** is loosened so that the second chuck **56** may be translated by the second Z axis slide assembly **66** and the servo drive **67** along the Z axis until the second chuck **56** is positioned adjacent the tool holders **58** and **60**. Then, the second chuck **56** is tightened on the bar stock **100** and, as the bar stock **100** is rotated by the chucks **54** and **56**, a cut-off tool (not shown) held by either of the tool holders **59**,**60** is used to cut through the bar stock **100** to create a second end **104** and an accurately-sized workpiece **106**.

As best seen in FIG. 4D, after the second end **104** and the workpiece **106** have been cut from the bar stock **100**, the end **104** of the workpiece **106** is machined by cutting tools (not shown) held in the first and second tool holders **58** and **60**. In this mode, X axis translations of the cutting tools relative to the end **104** are provided by the X axis slide **62** and the servo motor **63**, while Z axis translations of the cutting tools relative to the end **104** are provided by the second Z axis slide **66** and the servo motor **67** which translate the rotating workpiece **106** and the chuck **56** relative to the first Z axis slide assembly **64**, the X axis slide assembly **62**, and the tool holders **60** and **58** which are all held stationary relative to the frame in the Z axis by the fixing means **80**.

As best seen in FIG. 4E, after the machining of the end **104** has been completed, the workpiece **106** is translated to the right along the Z axis by the second Z axis slide assembly **66** and the servo motor **67** so that the workpiece **106** may be engaged by a robot arm **110**. After the robot arm **110** engages

the workpiece **106**, the second chuck **56** is released from the workpiece **106** and translated to the left along the Z axis by the second Z axis slide assembly **66** and the servo motor **67** to remove the workpiece **106** from the machine tools **50**,**51** as best seen in FIG. 4F. Alternatively, after the machining of the end **104** has been completed, the workpiece may be removed manually by an operator.

After the workpiece **106** has been removed from the machine tools **50**,**51**, the process outlined above is repeated to create a plurality of workpieces **106**.

From the foregoing, it will be appreciated that the disclosed method and apparatus allow for the machining of a workpiece having a long shaft section by a machine tool requiring only three slide assemblies and two servo motors (or other suitable actuators) for translating the slide assemblies. Accordingly, the cost of the machine tools **50**,**51** may be reduced when compared to the conventional machine tool **10** requiring four axis slide assemblies and four servo motors for translating the axis slide assemblies.

While this invention has been described in terms of the specific embodiments set forth in detail, it will also be appreciated that these are by way of illustration only and that the invention is not necessarily limited thereto. Modifications and variations will be apparent from this disclosure and may be resorted to without departing from the spirit of this invention, as those skilled in the art will readily understand. For example, while the invention has been described in the form of CNC lathes **50** and **51**, the invention could be applied equally well to a machine tool which utilizes a rotating cutting tool while the workpiece is held in a nonrotating fashion, and wherein the Z axis translation of the cutting tool relative to the workpiece is provided by a servo drive motor associated with a slide assembly carrying the workpiece holder. Accordingly, such variations and modifications of the disclosed method and apparatus are considered to be within the purview and scope of this invention and the following claims.

CLAIMS

What is claimed is:

1. A machine tool assembly comprising:

a frame;

first means on the frame for holding a cutting tool to machine a workpiece;

second means on the frame for translating the first means along a first axis relative to the frame;

third means on the frame for mounting the first means for translation along a second axis relative to the frame;

fourth means on the frame for holding a workpiece to be machined by a cutting tool held in the first means;

fifth means on the frame for holding a workpiece to be machined by a cutting tool held in the first means;

sixth means on the frame for translating the fifth means along the second axis; and

seventh means for selectively connecting the first means to the fifth means for translation of the first means by the sixth means along the second axis.

2. The machine tool of claim **1** wherein said first means is a turret holding a plurality of cutting tools.

3. The machine tool of claim **1** wherein said second means comprises:

a slide assembly carrying the first means; and

a servo motor driving the slide assembly.

4. The machine tool of claim **1** wherein said third means is a slide assembly carrying the second means.

5. The machine tool assembly of claim 1 wherein:

the fourth means includes a first rotatable element for driving a workpiece as it is machined by a cutting tool; and

the fifth means includes a second rotatable element for driving a workpiece as it is machined by a cutting tool.

6. The machine tool of claim 1 wherein said sixth means comprises:

a slide assembly carrying the fifth means; and

a servo motor driving the slide assembly.

7. The machine tool of claim 1 wherein said seventh means comprises:

an aperture in one of the first, second, and third means;

a lock pin carried on one of the fifth and sixth means; and

a servo carried on the one of the fifth and sixth means for selectively extending the lock pin into engagement with the aperture.

8. The machine tool of claim 1 further comprising eighth means on the frame for selectively fixing the third means to the frame to prevent translation of the first means along the second axis.

9. The machine tool of claim 8 wherein the eighth means comprises:

an aperture on one of the frame and the third means;

a lock pin carried by the other of the frame and the third means; and

a servo carried by the other of the frame and the third means for selectively extending the lock pin into engagement with the aperture.

10. The machine tool of claim 8 wherein the eighth means comprises a hydraulic cylinder having a first end connected to the frame and a second end connected to the third means.

11. The machine tool assembly of claim 1 further comprising ninth means for holding a cutting tool to machine a workpiece.

12. A machine tool assembly comprising:

a frame;

first means on the frame for mounting a cutting tool for translation along a first axis and a second axis to machine a workpiece;

second means on the frame for holding a workpiece to be machined by a cutting tool mounted by the first means;

third means on the frame for holding a workpiece to be machined by a cutting tool translated by the first means;

fourth means on the frame for translating the third means along the second axis; and

fifth means on the frame for selectively connecting the first means to the third means for translation of the first means by the fourth means along the second axis.

13. The machine tool assembly of claim 12 wherein:

the first means includes a tool holder, a first slide assembly carrying the tool holder for translation along the first axis, and a second slide assembly carrying the first slide assembly for translation along the second axis; and

the fourth means includes a third slide assembly carrying the third means and a servo motor for translating the third slide assembly.

14. A method of machining a workpiece, said method comprising the steps of:

providing a workpiece;

providing a cutting tool holder for holding a cutting tool to machine the workpiece;

providing a first workpiece holder;

providing a second workpiece holder that is translatable along a first axis;

loading said workpiece into said first workpiece holder;

connecting said cutting tool holder to said second workpiece holder; and

translating said cutting tool holder and said second workpiece holder together along said first axis while said workpiece is held by said first workpiece holder and machined by a cutting tool held in said cutting tool holder.

15. The method of claim 14 further comprising the steps of:

loading said workpiece into said second workpiece holder;

fixing said cutting tool holder relative to said first axis;

disconnecting said cutting tool holder from said second workpiece holder; and

translating said second workpiece holder and said workpiece together along said first axis while said workpiece is held by said second workpiece holder and machined by a cutting tool held in said cutting tool holder.

16. A method of processing a workpiece, said method comprising the steps of:

providing a workpiece;

providing a first workpiece holder;

providing a second workpiece holder that is translatable along a first axis;

holding said workpiece with said first workpiece holder while a first processing operation is performed on said workpiece;

releasing said workpiece from said first workpiece holder so that said workpiece may move relative to said first workpiece holder;

loading said workpiece into said second workpiece holder; and

drawing a length of said workpiece through said first workpiece holder while said second workpiece holder is translated along said first axis with the second workpiece holder holding said workpiece.

17. The method of claim 16 further comprising the steps of:

holding said workpiece with said first workpiece holder after said length has been drawn through said first workpiece holder;

releasing said workpiece from said second workpiece holder so that said second workpiece holder may move relative to said workpiece;

translating said second workpiece holder along said first axis while said workpiece is held by said first workpiece holder so that at least a portion of said length is translated through said second workpiece holder; and

performing a second processing operation on said workpiece holder while said workpiece is held by at least one of said first and second workpiece holders.

* * * * *

US005800104A

United States Patent [19]

Miyano

[11] **Patent Number: 5,800,104**

[45] **Date of Patent: Sep. 1, 1998**

[54] **LIQUID COOLANT/LUBRICANT RECOVERY SYSTEM FOR MACHINE TOOLS**

[76] Inventor: **Toshiharu Tom Miyano**, 50 Dundee La., Barrington Hills, Lake County, Ill. 60010

[21] Appl. No.: **631,785**

[22] Filed: **Apr. 12, 1996**

[51] **Int. Cl.**[6] **B23Q 11/00**; B01D 21/00

[52] **U.S. Cl.** **409/131**; 29/DIG. 94; 82/901; 210/168; 408/56; 409/136; 409/137

[58] **Field of Search** .... 409/137, 136, 409/131; 29/DIG. 28, DIG. 94, DIG. 63, DIG. 71; 408/56; 210/222, 703, 774, 168, 123, 171; 82/901

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Primary Examiner—William R. Briggs
Attorney, Agent, or Firm—Wood, Phillips, VanSanten, Clark & Mortimer

[57] **ABSTRACT**

A method of for performing a machining operation and recovering a liquid used in the machining operation. The method includes the steps of providing a machine tool to perform a machining operation, directing a liquid against at least one of a) a part of the machine tool and b) a workpiece on which the machining operation is being performed by the machine tool in such a manner that discrete particles become entrained in the liquid, directing at least a part of the liquid with the discrete particles entrained therein to a first location, and at the first location separating the liquid from the discrete particles.

9 Claims, 3 Drawing Sheets

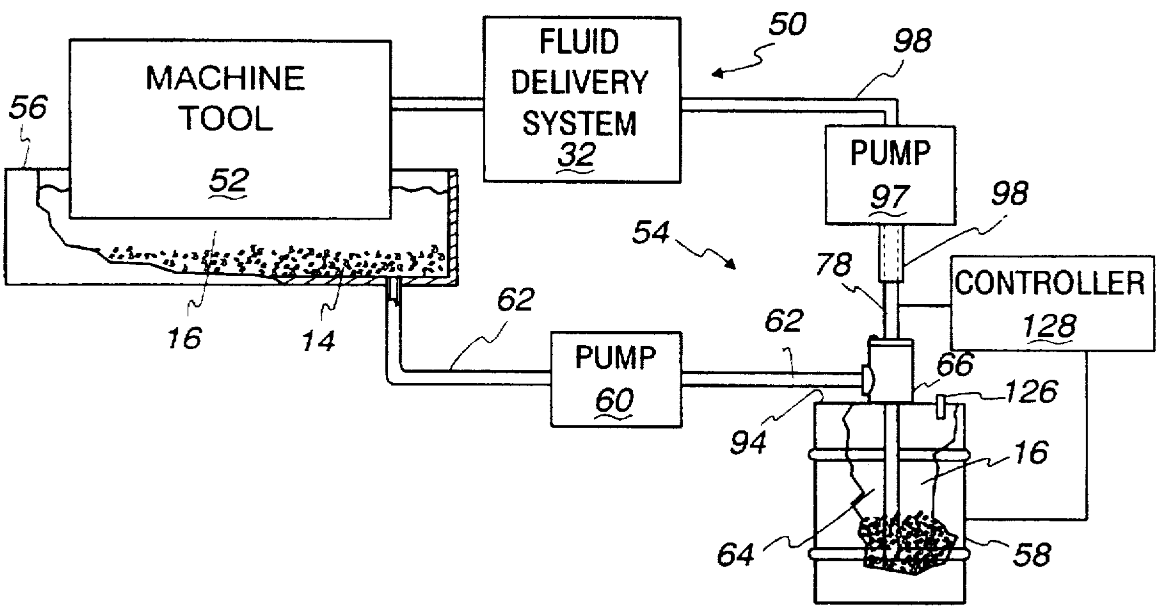


Fig. 1
(Prior Art)

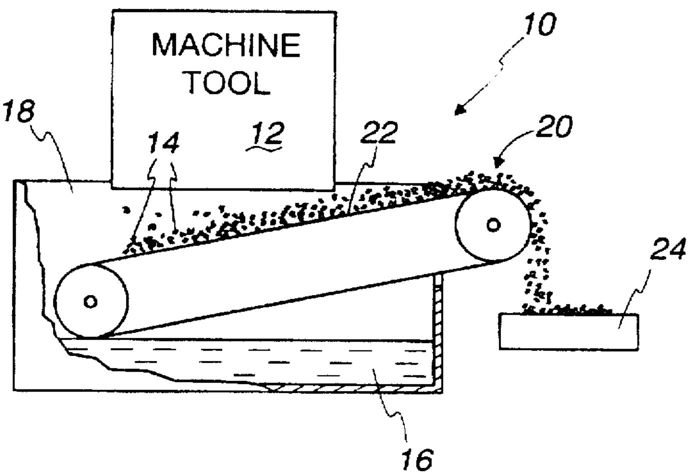


Fig. 2
(Prior Art)

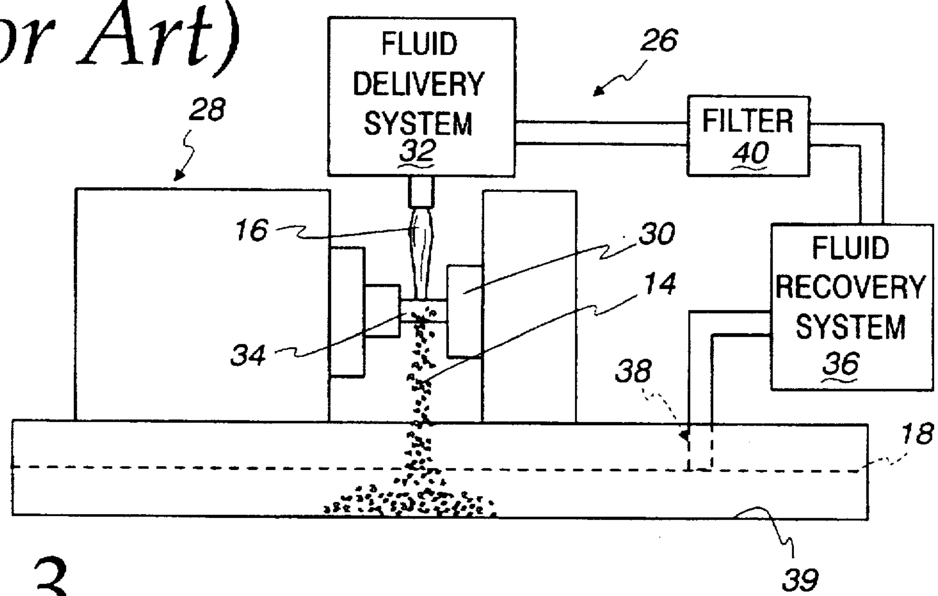
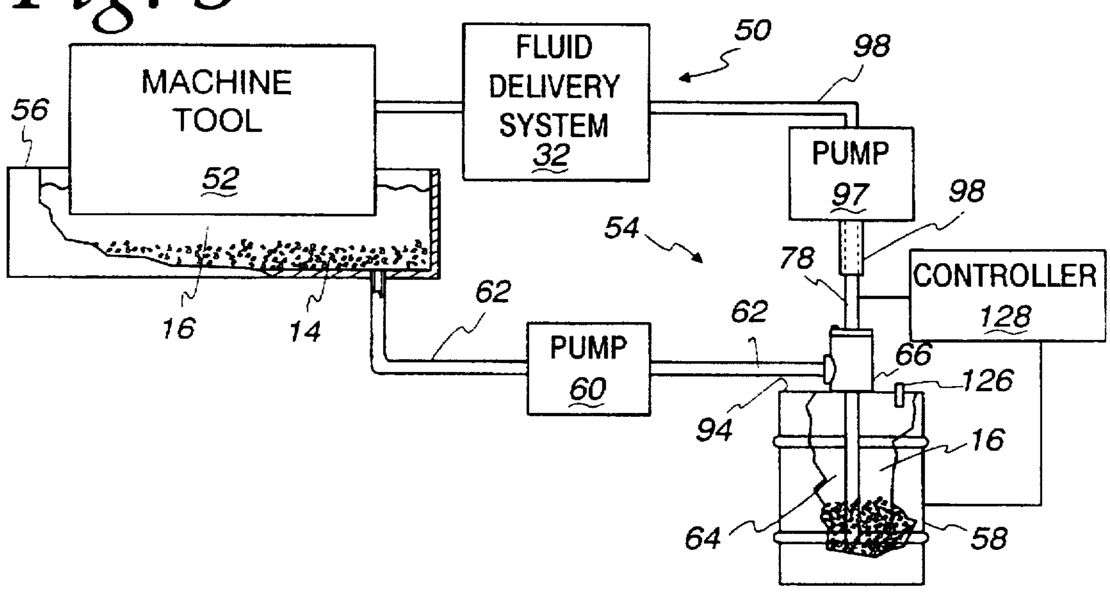


Fig. 3



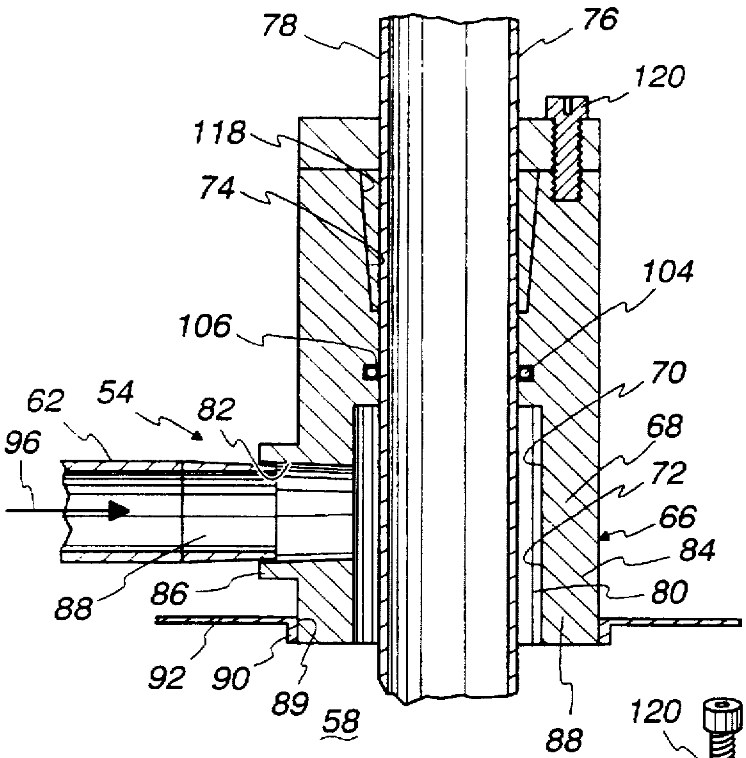

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Fig. 4

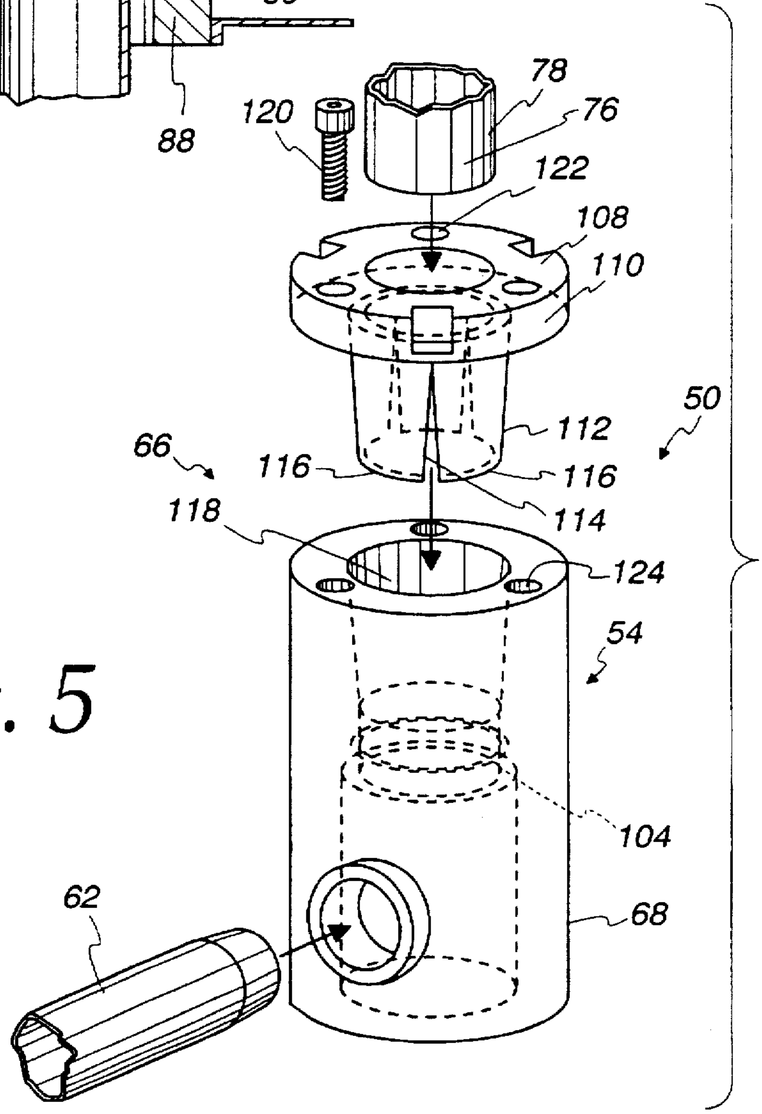
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Fig. 5

Fig. 6

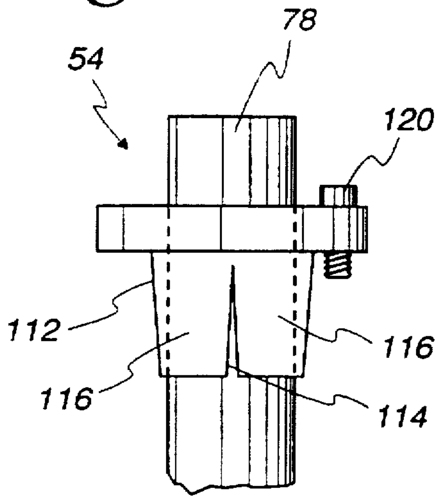


Fig. 7

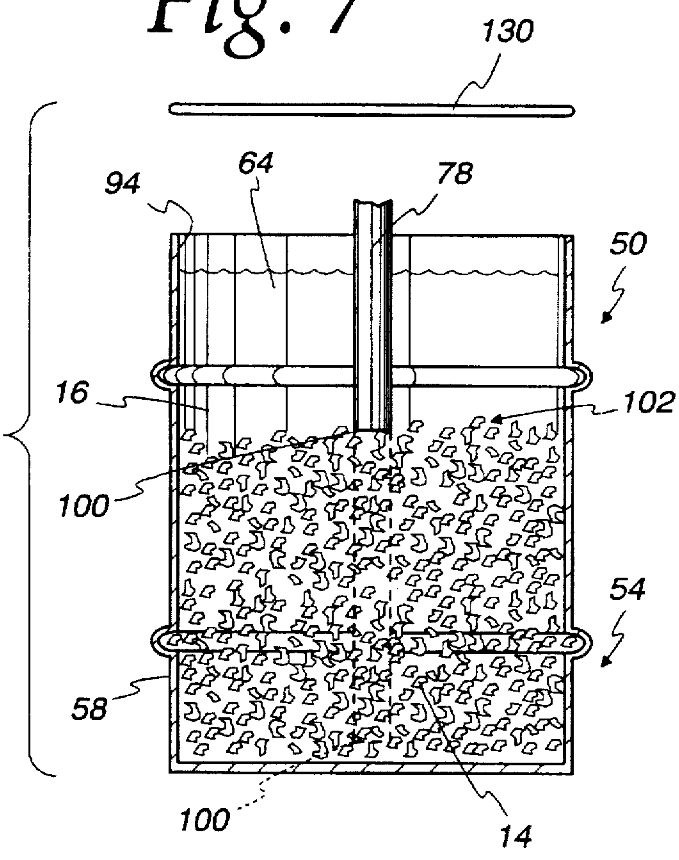
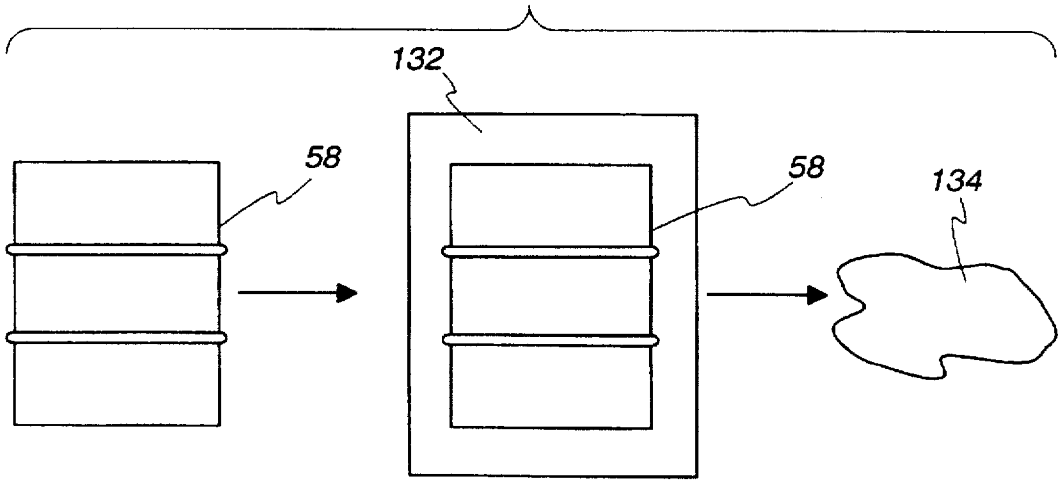


Fig. 8



LIQUID COOLANT/LUBRICANT RECOVERY SYSTEM FOR MACHINE TOOLS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to machine tools which utilize a liquid coolant/lubricant during machining operations and, more particularly, to a method of recovering used coolant/lubricant and separating and accumulating solid machined particles entrained in the liquid for disposal thereof.

2. Background Art

It is well known to use liquid coolants and lubricants during machining operations. Coolants and lubricants enhance the performance of various tools and prevent overheating of both the workpiece and the tools during these operations.

Coolants and lubricants may be used in virtually every machining operation in which a tool removes particles or chips from a workpiece. During some machining operations, liquid under pressure may be continuously directed at part of the machine tool and/or the workpiece during the entire machining operation. As a result, bulk quantities of the coolant/lubricant are used. It is cost prohibitive and ecologically impractical to dispose of this liquid after a single use. Accordingly, many prior art machining systems recover this liquid for reuse.

In a typical system, a fluid collection trough is provided beneath the location where the machining operation takes place. The liquid that is discharged at the machine tool and/or workpiece accumulates in the collection trough. During the machining operation, discrete particles are removed from the workpieces and fall down towards the collection trough. In some prior art systems, a conveyor intercepts larger discrete particles and trimmings from the workpieces and conveys these particles to an appropriate disposal location. However, the smaller discrete particles migrate through the conveying system and become entrained in the liquid in the collection trough and define what is commonly referred to as "sludge". This is a thickened mixture of the coolant/lubricant liquid with small discrete particles that are removed from workpieces. If the sludge is allowed to stand undisturbed, the small particles, which are denser than the liquid, eventually fall under their own weight and accumulate, with the liquid above the accumulation of particles being relatively clear i.e. free of workpiece particles.

It is known to draw the clear liquid from above the accumulation of particles in the collection trough and to circulate this liquid back to against part of the machine tool and/or the workpiece as the machining operation continues. One problem associated with this type of system is that the small discrete workpiece particles continue to accumulate in the collection trough to the point that they must be removed. Consequently, this condition must be constantly monitored. Failure to extract the accumulated particles may result in a situation where the particles may interfere with the chip conveying structure or the basic components of the machine tool. At some point before this extreme condition occurs, the recirculating system may be drawing a significant amount of sludge out of the collection trough for recirculation. This may result in clogging of the filtering system or, in the absence of an effective filtering system, passage of particle-laden liquid to against the machine tool and/or workpiece, which could ultimately affect the machine tool operation.

Another problem with the conventional systems, described above, is that when the discrete particles and thick

sludge are removed from the collection trough, this mixture must be disposed of. Since the liquid coolant/lubricant may contain toxic components, it is necessary to dispose of this material without violation of any disposal regulations or injury to the environment. In high volume operations, this disposal process may represent a significant expense.

SUMMARY OF THE INVENTION

It is one objective of the present invention to overcome one or more of the problems with the prior art, identified above.

In one form of the invention, a method is provided for performing a machining operation and recovering a liquid used in the machining operation. The method includes the steps of providing a machine tool to perform a machining operation, directing a liquid against at least one of a) a part of the machine tool and b) a workpiece on which the machining operation is being performed by the machine tool in such a manner that discrete particles become entrained in the liquid, directing at least a part of the liquid with the discrete particles entrained therein to a first location, and at the first location separating the liquid from the discrete particles.

The method may further include the step of directing at least a part of the liquid separated from the discrete particles against at least one of a) a part of a machine tool and b) a workpiece on which a machining operation is being performed by the machine tool.

According to the invention, a useable, solid product can be formed from the discrete particles from which the liquid is separated.

In one form, the step of separating the liquid from discrete particles involves directing the liquid with discrete particles entrained therein into a receptacle and allowing discrete particles that are denser than the liquid to move by gravity downwardly in the liquid in the receptacle.

The step of directing at least a part of the liquid separated from discrete particles may include the steps of providing a conduit with an inlet for conveying the liquid, situating the inlet of the conduit in the receptacle, and raising the inlet in the receptacle as the discrete particles accumulate in the receptacle.

The receptacle may be suitably closed once the accumulation of particles has reached a desired depth and replaced with another receptacle.

The liquid can be directed to the first location continuously as a machining operation is being performed. Similarly, direction of the part of the liquid separated from the discrete particles against the part of the machine tool and/or workpiece may also be carried out continuously as a machining operation is being performed.

The invention is also directed to a machining system including a machine tool for performing a machining operation on a workpiece, structure for collecting a liquid directed against at least one of a) part of the machine tool and b) a workpiece on which a machining operation is being performed by the machine tool, a receptacle in which liquid can be separated from discrete particles entrained in the liquid, and structure for directing liquid collected by the collecting structure to the receptacle.

The system may include structure for directing liquid from the receptacle back to the machine tool.

In one form, the machine tool has structure for directing liquid under pressure against at least one of a) a part of the machine tool and b) a workpiece on which a machining

operation is being performed by the machine tool, and the structure for directing liquid back to the machine tool directs the liquid under pressure against a least one of a) a part of the machine tool and b) a workpiece on which a machining operation is being performed by the machine tool.

The structure for directing liquid to the receptacle may continuously direct liquid to the receptacle as a machining operation is being performed by the machine tool.

The structure for directing liquid back to the machine tool may continuously direct liquid back to the machine tool as a machining operation is being performed.

The system may further include structure for directing liquid separated from discrete particles away from the receptacle to a point of use. This structure may include a conduit for conveying liquid and having an inlet, and structure cooperating between the receptacle and conduit for selectively varying the location of the inlet within the receptacle.

In one form, the structure for directing liquid away from the receptacle includes a sleeve with a through bore in which the conduit is guided to thereby move relative to the receptacle, with the sleeve defining a passage separate from the through bore to communicate liquid from the collecting structure to the receptacle.

In one form, the receptacle is a drum with an open top and has a lid that can be used to selectively close the top.

The invention is further directed to a receptacle for separating a liquid from particles entrained in the liquid, which receptacle has a main body defining a liquid receiving and storing space, a sleeve, structure for attaching the sleeve to the main body, a conduit having an inlet, structure cooperating between the conduit and sleeve for guiding relative movement between the sleeve and main body to thereby vary the location of the inlet on the conduit in the receiving and storing space, and structure on the sleeve defining a communication path for liquid with discrete particles entrained therein from a location externally of the receptacle to within the liquid receiving and storing space without travelling through the conduit.

In one form, the communication path is bounded by the conduit.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic, side elevation view of a conventional machining system including a collection trough for a liquid coolant/lubricant used during machining operations and a conveying system for directing machined workpiece particles away from the collection trough;

FIG. **2** is a schematic, side elevation view of a prior art machining system including a system for recirculating liquid coolant/lubricant;

FIG. **3** is a schematic, side elevation view of a machining system, according to the present invention, and including a receptacle/drum into which sludge is directed to allow separation of discrete particles from a liquid coolant/lubricant in which the discrete particles are entrained in the sludge;

FIG. **4** is an enlarged, fragmentary, cross-sectional view of a sleeve, according to the present invention, for controlling introduction of sludge into the drum, and delivery of liquid separated out of the sludge in the receptacle/drum from the receptacle/drum;

FIG. **5** is an enlarged, exploded, perspective view of the sleeve of FIG. **4**;

FIG. **6** is an enlarged, fragmentary, side elevation view of the top of the sleeve of FIGS. **4** and **5**;

FIG. **7** is a cross-sectional view of the receptacle/drum in FIG. **3** with a removable lid separated therefrom and with a conduit for conveying liquid from within the receptacle/drum in two different positions; and

FIG. **8** is a schematic representation of the steps used to convert the receptacle/drum filled with discrete particles into a solid, useable object having a different configuration.

DETAILED DESCRIPTION OF THE DRAWINGS

In FIG. **1**, a prior art machining system is shown schematically at **10**. The machining system **10** includes a machine tool **12**. The machine tool **12** is shown generically to encompass any type of machine tool that operates on a workpiece to thereby separate discrete particles **14** from the workpiece during a machining operation.

During a machining operation, it is conventional to deliver a supply of liquid coolant/lubricant **16** under pressure against a part of the machine tool and/or a workpiece being operated upon by the machine tool **12**. The discharged liquid coolant/lubricant **16** accumulates in a collection trough **18** defined beneath the machine tool **12**. The larger particles **14** that are removed from the workpiece are intercepted by a conveying system **20** with a porous conveying belt **22**, which allows the smaller discrete particles **14** and the liquid coolant/lubricant **16** to pass therethrough and be accumulated in the collection trough **18**. The larger discrete particles **14** are moved by the conveying system **20** away from the machine tool **12** to an appropriate bin **24** for collection thereat.

In FIG. **2**, a prior art machining system is shown schematically at **26** and includes a machine tool **28** for operating on a workpiece **30**. A fluid delivery system **32** propels liquid coolant/lubricant **16** against a working tool **34** and a workpiece **30** as it is operated upon by the working tool **34**. The liquid **16** and discrete workpiece particles **14** removed from the workpiece **30** during the machining operation accumulate in the collection trough **18**.

The machining system **26** has a fluid recovery system **36** which draws liquid coolant/lubricant **16** from a location **38** above the bottom **39** of the collection trough **18**. This type of recovery system **36** relies on the fact that the majority of the discrete particles **14** will have a higher density than that of the liquid coolant/lubricant **16** and will, as a result, fall under their own weight towards the bottom **39** of the collection trough **18**, and accumulate thereat. As a result, the liquid **16** drawn at the location **38** will be relatively free of discrete particles **14**. The fluid recovery system **36** directs the liquid coolant/lubricant **16** drawn from the collection trough **18** through a filter **40** into the fluid delivery system **32** so that the liquid coolant/lubricant **16** can be redirected at the machine tool **28** and workpiece **30**.

The problems with the systems shown in FIGS. **1** and **2** are described in the Background Art section, above.

The present invention is described with respect to FIGS. **3–8**. Referring initially to FIGS. **3–7**, the inventive machining system is shown at **50**. The machining system **50** is made up of a machine tool **52** and a fluid recovery system at **54**. The machine tool **52** is again shown schematically in FIG. **3** to be a generic representation of any type of machine tool that operates on a workpiece in such a manner that discrete particles on the workpiece are removed during the machining operation.

A collection trough **56** is provided beneath the machine tool **52** and is designed to accumulate liquid coolant/lubricant **16** directed against a part of the machine tool **52** and/or a workpiece operated upon by the machine tool **52**

during a machining operation in the same manner as shown in FIGS. 1 and 2. A screen or a conveying system, such as that shown in 20 in FIG. 1, can be incorporated into the system 50 to intercept large discrete particles that are separated from a workpiece during the machining operation.

According to the invention, a receptacle, in this case shown in the form of a drum 58, is provided at a location spaced from the machine tool 52. A pump 60 directs sludge, made up of discrete particles 14 entrained in the liquid coolant/lubricant 16, from the bottom of the collection trough 56 through a conduit 62 to a receiving and storage space 64 within the receptacle 58.

More particularly, the conduit 62 communicates through a sleeve/fitting 66 with the space 64. The sleeve/fitting 66 has a cylindrical body 68 with a stepped through bore 70. The bore 70 has a large diameter portion 72 and a small diameter portion 74. The small diameter portion 74 closely accepts the outer surface 76 of a discharge conduit 78, as described in detail hereafter. The large diameter portion 72 of the bore 70 and outer surface 76 of the conduit 78 cooperatively define an annular chamber 80. A bore 82 through the side wall 84 of the body 68 is in fluid communication with the chamber 80. A thickened flange 86 surrounds the bore 82 and defines a seating surface for a tapered end 88 of the conduit 62.

The lower end 88 of the sleeve/fitting 66 is press fit into a through bore 89 in a thickened portion 90 of a lid 92 at the open upper end 94 of the receptacle 58. With the sleeve/fitting 66 in the operative position of FIG. 4, the sludge pumped from the trough 56 is allowed to flow in the direction of the arrow 96 through the conduit 62, through the chamber 80, and into the receiving and storing space 64 in the receptacle 58.

In the receptacle 58, the particles 14 in the sludge fall by their own weight to the bottom of the receiving and storage space 64 and accumulate thereat. As this occurs, the liquid 16 becomes separated therefrom. This relatively clean fluid 16 is then drawn by a pump 96 through the conduit 78 and delivered to a conduit 98 and to the fluid delivery system 58, which may include a suitable filter to block passage of any remaining particles 14.

According to the invention, the conduit 78 is slidable vertically within the conduit 98 and sleeve/fitting 66 relative to the receptacle 58 so that an inlet 100, at the bottom end of the conduit 78, can be situated above the accumulation 102 of particles 14 separated in the receptacle 58. With this arrangement, the user can periodically raise the conduit 78 so that the inlet 100 draws relatively clean liquid 16 from the receptacle 58 above the accumulated discrete particles 14.

As previously noted, the outer surface 76 of the conduit 78 is guided within the small diameter portion 74 of the through bore 70. To prevent passage of liquid between the conduit 78 and sleeve/fitting 66, an O-ring 104 is located in an undercut 106 on the body 68. The O-ring 104 sweeps the outer conduit surface 76 as the conduit 78 is raised relative to the receptacle 58.

The conduit 78 can be fixed in any desired position by a collet 108 having a disk-shaped flange 110, from which a tapered sleeve 112 depends. The sleeve 112 has slots 114 therethrough which define tabs 116. The sleeve 112 is received within a correspondingly tapered seat 118 at the top of the body 68. Bolts 120 extend through bores 122 in the flange 110 and into threaded, blind bores 124 extending axially into the side wall 84 of the sleeve/fitting 66. As the bolts 120 are tightened, the tabs 116 produce a progressively increasing captive force on the outer surface 76 of the

conduit 78. With the collet 108 loosened, the conduit 78 can be slid vertically to situate the inlet 100 at a desired vertical location within the receptacle 58 i.e. preferably above the top of the accumulation 102 of the particles 14 therein.

To begin operation, the user first sets the conduit 78 so that the inlet 100 thereon is situated towards the bottom of the receiving and storage space 64 in the receptacle 58. Pumps 90, 96 are then operated to continuously circulate liquid from the collection trough 56 to the fluid delivery system 58 through the receptacle 58, in which the discrete particles 14 are allowed to separate from the liquid coolant/lubricant 16. An air vent 126 in the lid 92 on the receptacle 58 assures the free flow of liquid to and from the receptacle 58. As the liquid 16 circulates, there is a progressive buildup of particles 14 in the receptacle 58. As this occurs, the user periodically loosens the collet 108 and raises the conduit 78 so that the inlet 100 thereon is in relatively clean liquid 16, i.e. not embedded in an accumulation of the particles 14 in the receptacle 58.

In a more sophisticated version of the system, as shown in FIG. 3, a controller 128 can be provided to sense the quantity of discrete particles 14 within the receptacle, as by weight, and to thereby automatically change the vertical position of the conduit 78 to situate the inlet above the particle accumulation. This can be done without fixing the conduit 78, as to the collet 108.

When the receptacle 58 is filled to a predetermined height with discrete particles 14, the receptacle 58 is replaced with a like, but empty, receptacle 58. To accomplish this, the user removes the lid 92 with the sleeve/fitting 66 thereon and substitutes a solid lid 130, as shown in FIG. 7, to seal the upper end 94 of the receptacle 58. The substitute receptacle 58 is hooked up and functions in the same manner as previously described.

The receptacle 58 that is full and sealed can then be transported to a dump site. Alternatively, the invention contemplates that the receptacle 58 and its contents i.e. discrete particles 14, can be converted to another state. As shown in FIG. 8, the receptacle 58 with the accumulated discrete particles 14 can be directed into a furnace 132 and melted to be thereafter converted to another useable, solid form, as shown schematically at 134. Since the majority of the discrete particles 14 will be metal, the melted mass can be converted into a ballast material, such as used in a counterbalance in heavy machinery. Rather than having to dispose of this material, the user of the machine tool can sell the sealed drums with the discrete particles therein for this purpose or other appropriate use.

The foregoing disclosure of specific embodiments is intended to be illustrative of the broad concepts comprehended by the invention.

I claim:

1. A method of performing a machining operation and recovering a liquid used in the machining operation, said method comprising the steps of:

providing a machine tool to perform a machining operation;

providing at a first location a first receptacle having a storing space with a top and bottom;

directing a liquid against at least one of a) a part of the machine tool and b) a workpiece on which the machining operation is being performed by the machine tool in such a manner that discrete particles become entrained in the liquid;

directing at least a part of the liquid with the discrete particles entrained therein into the receptacle storing space;

allowing discrete particles that are denser than the liquid to move under gravitational force and progressively accumulate at the bottom of the receptacle storing space;

providing a return path from said receptacle to said machine tool so that liquid from above the accumulated discrete particles in the receptacle storing space is directed against at least one of a) a part of the machine tool and b) a workpiece on which a machining operation is being performed by the machine tool until the accumulated discrete particles in the receptacle storing space accumulate to a predetermined height in the receptacle storing space;

moving the receptacle with the discrete particles therein accumulated to the predetermined height from the first location to a point of use; and

providing at the first location a second receptacle having a storing space with a top and bottom and directing at least part of the liquid with the discrete particles entrained therein into the second receptacle to cause progressive accumulation of discrete particles at the bottom of the storing space in the second receptacle.

2. The method of performing a machining operation and recovering a liquid used in the machining operation according to claim 1 including the step of directing at least a part of the liquid separated from discrete particles in the receptacle against at least one of a) a part of the machine tool and b) a workpiece on which a machining operation is being performed by the machine tool.

3. A method of performing a machining operation and recovering a liquid used in the machining operation, said method comprising the steps of:

providing a machine tool to perform a machining operation;

directing a liquid against at least one of a) a part of the machine tool and b) a workpiece on which the machining operation is being performed by the machine tool in such a manner that discrete particles become entrained in the liquid;

directing at least a part of the liquid with the discrete particles entrained therein to a first location;

at the first location separating the liquid from discrete particles;

wherein the step of separating the liquid from discrete particles comprises the steps of directing the liquid with discrete parties entrained therein into a receptacle and allowing discrete particles that are denser than the liquid to move by gravity downwardly in the liquid in the receptacle; and

directing at least a part of the liquid separated from discrete particles in the receptacle against at least one of a) a part of the machine tool and b) a workpiece on which a machining operation is being performed by the machine tool,

wherein the step of directing at least a part of the liquid separated from discrete particles comprises the steps of

providing a conduit with an inlet for conveying the liquid, situating the inlet of the conduit in the receptacle, and raising the inlet in the receptacle as the discrete particles accumulate in the receptacle.

4. The method of performing a machining operation and recovering a liquid used in the machining operation according to claim 3 including the steps of closing the receptacle once the discrete particles are accumulated to a desired depth and replacing the receptacle with another receptacle.

5. The method of performing a machining operation and recovering a liquid used in the machining operation according to claim 1 wherein the step of directing at least a part of the liquid into the receptacle storing space of the first receptacle comprises the step of continuously directing at least a part of the liquid into the receptacle storing space of the first receptacle as the machining operation is being performed.

6. The method of performing a machining operation and recovering a a liquid used in the machining operation according to claim 5 wherein the step of directing at least a part of the liquid separated from discrete particles comprises the step of continuously directing at least a part of the liquid separated from discrete particles against at least one of a) a part of the machine tool and b) a workpiece on which a machining operation is being performed by the machine tool as the machining operation is being performed.

7. A machining system comprising:

a machine tool for performing a machining operation on a workpiece,

means for collecting a liquid directed against at least one of a) a part of the machine tool and b) a workpiece on which a machining operation is being performed by the machine tool;

a receptacle in which liquid can be separated from discrete particles entrained in the liquid;

means for directing liquid collected by the collecting means to the receptacle; and

means for directing liquid separated from discrete particles away from the receptacle to a point of use,

wherein the means for directing liquid away from the receptacle comprises a conduit for conveying liquid and having an inlet and means cooperating between the receptacle and conduit for selectively varying the location of the inlet within the receptacle.

8. The machining system according to claim 7 wherein the means for directing liquid away from the receptacle comprises a sleeve with a through bore in which the conduit is guided to thereby move relative to the receptacle and the sleeve defines a passage separate from the through bore to communicate liquid from the collecting means to the receptacle.

9. The machining system according to claim 7 wherein the receptacle comprises a drum with an open top and a lid that can be used to selectively close the top.

* * * * *

US005820098A

United States Patent [19]

Miyano

[11] **Patent Number: 5,820,098**

[45] **Date of Patent: Oct. 13, 1998**

[54] **STRUCTURAL FRAME FOR SLANT-BED MACHINE TOOL**

[76] Inventor: **Toshiharu Tom Miyano**, c/o Miyano Machinery USA Inc., 940 N. Central Ave., Wood Dale, Ill. 60191

[21] Appl. No.: **626,508**

[22] Filed: **Apr. 2, 1996**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 543,061, Oct. 13, 1995, abandoned.

[51] **Int. Cl.**[6] **B23B 17/00**

[52] **U.S. Cl.** **248/637**; 82/149

[58] **Field of Search** .... 248/637, 671, 248/673, 676, 678; 82/149, 27 R, 27 C

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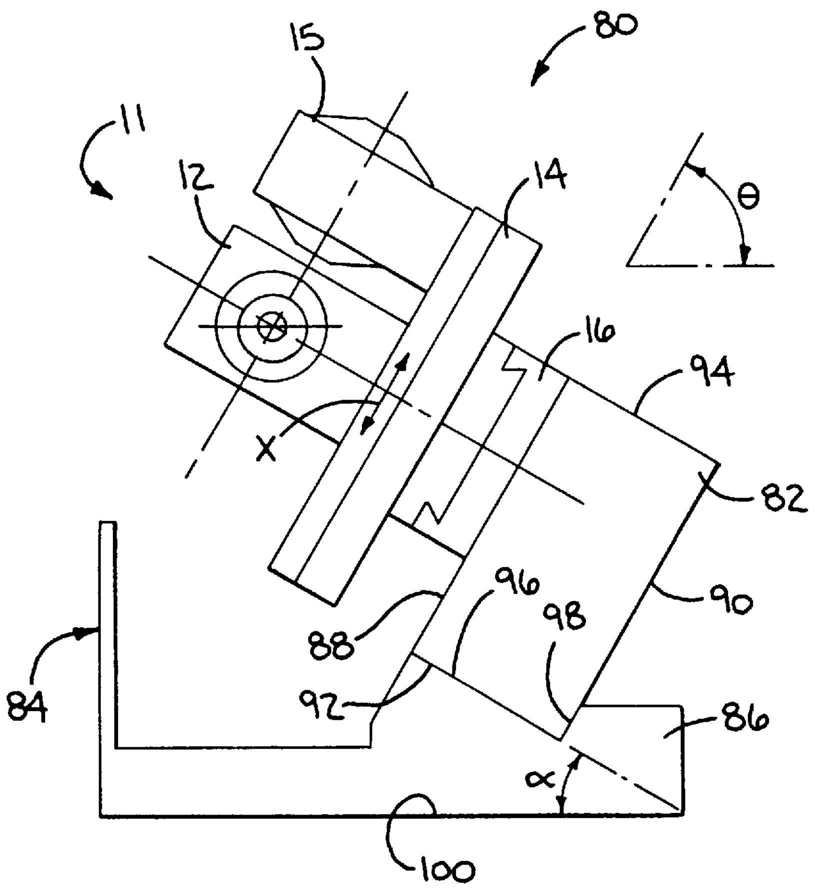
Primary Examiner—Ramon O. Ramirez
Assistant Examiner—Long Dinh Phan
Attorney, Agent, or Firm—Wood, Phillips, VanSanten, Clark & Mortimer

[57] **ABSTRACT**

A slant-bed structural frame is provided for a slant-bed machine tool. The structural frame includes a bed element having a first flat surface on which the bed element can be supported in a machining position and a second machined, flat surface that is parallel to the first surface and at least partially formed with the bed element supported on the first surface. The second surface defines a support for an operating component of the machine tool. Additionally, a base element is provided having a third surface. The third surface cooperates with a surface on the bed element to maintain the bed element in an operative position on the base element, wherein the second surface is neither fully vertical nor fully horizontal.

10 Claims, 5 Drawing Sheets



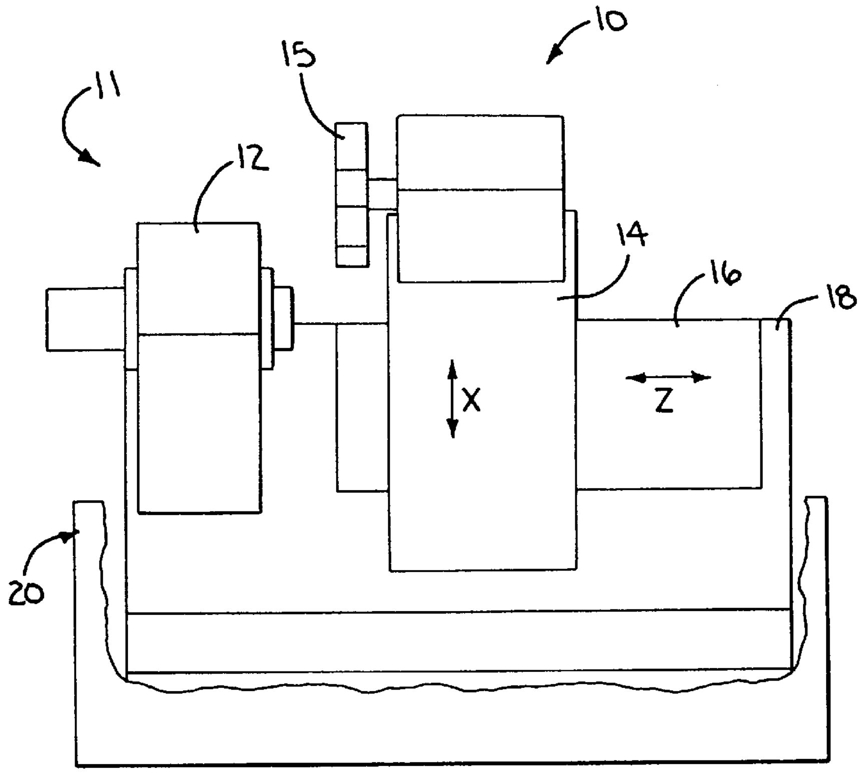


FIGURE 1
PRIOR ART

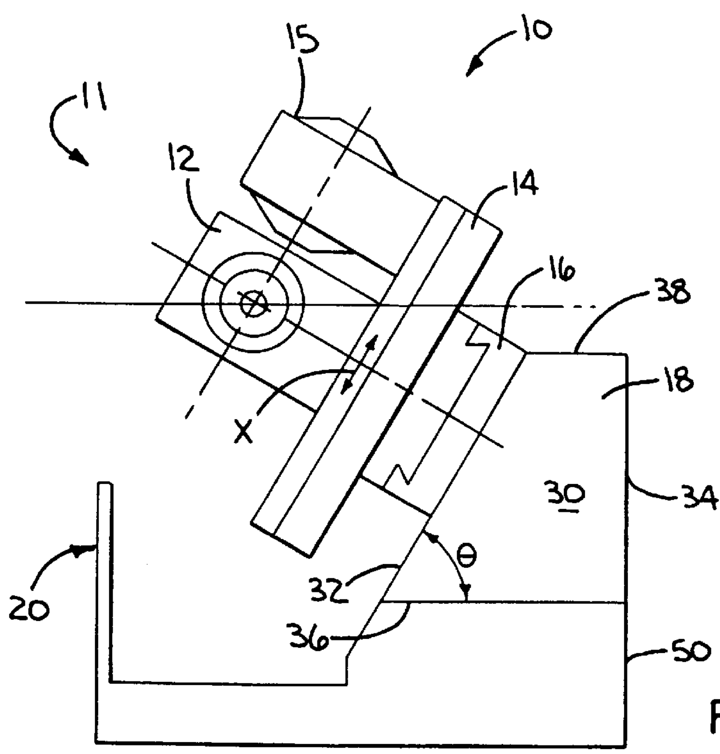


FIGURE 2
PRIOR ART

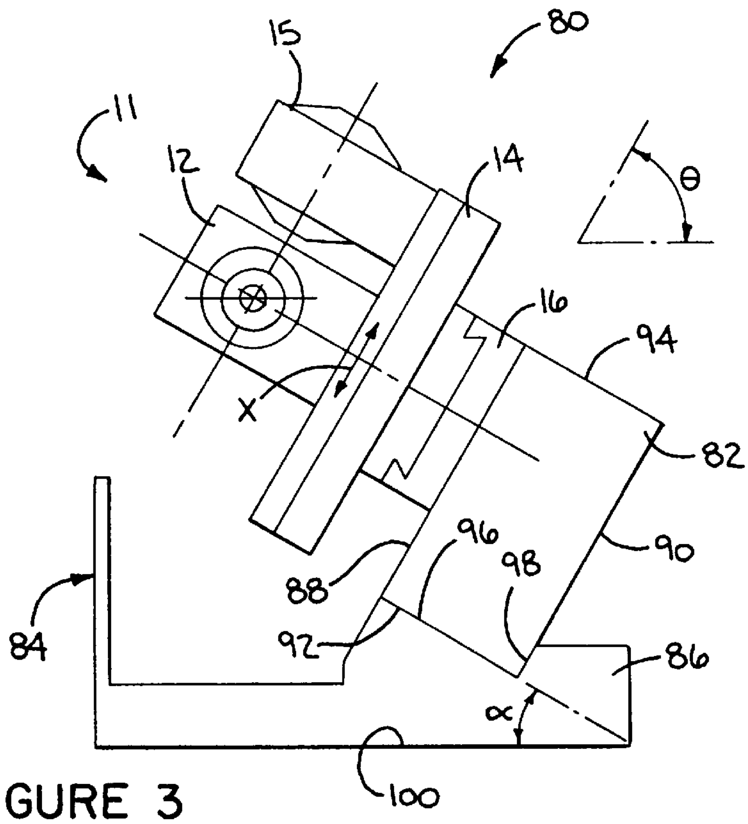


FIGURE 3

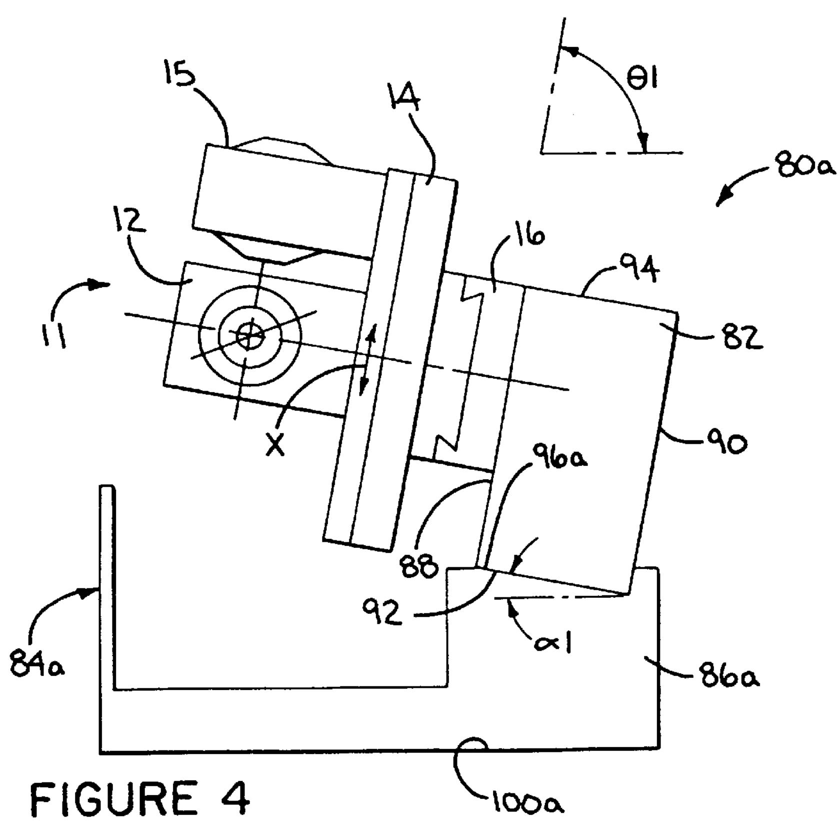


FIGURE 4

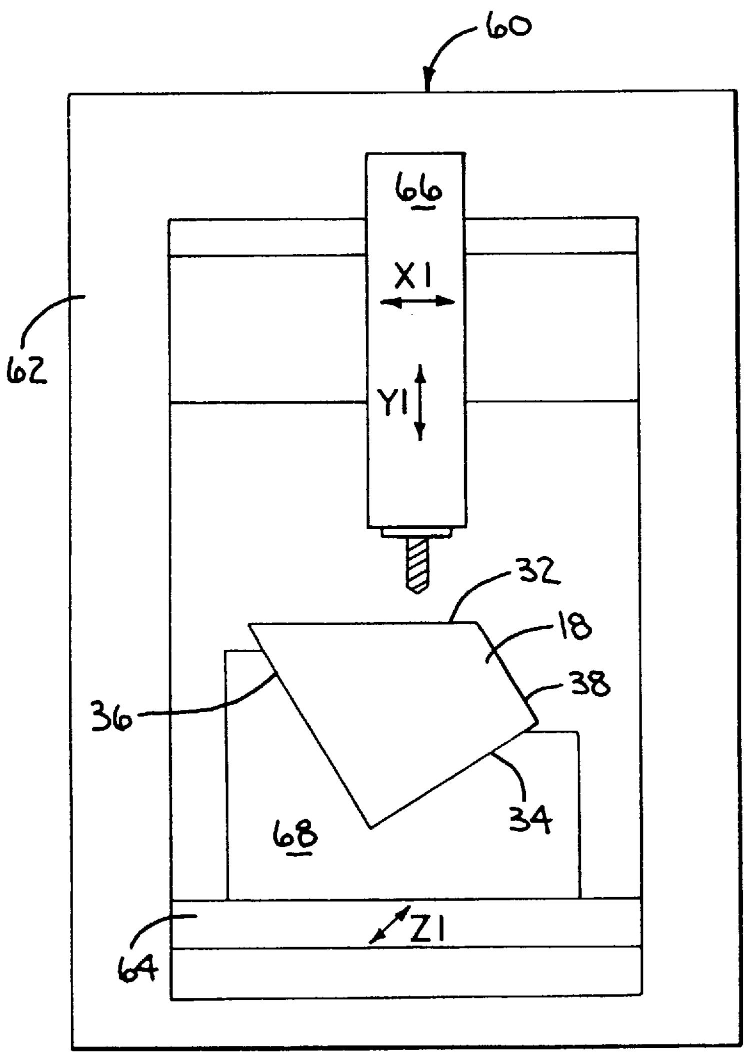


FIGURE 5
PRIOR ART

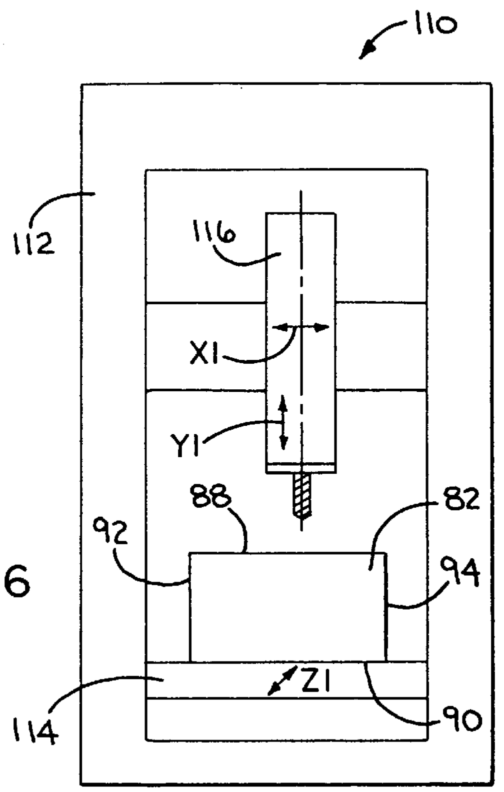


FIGURE 6

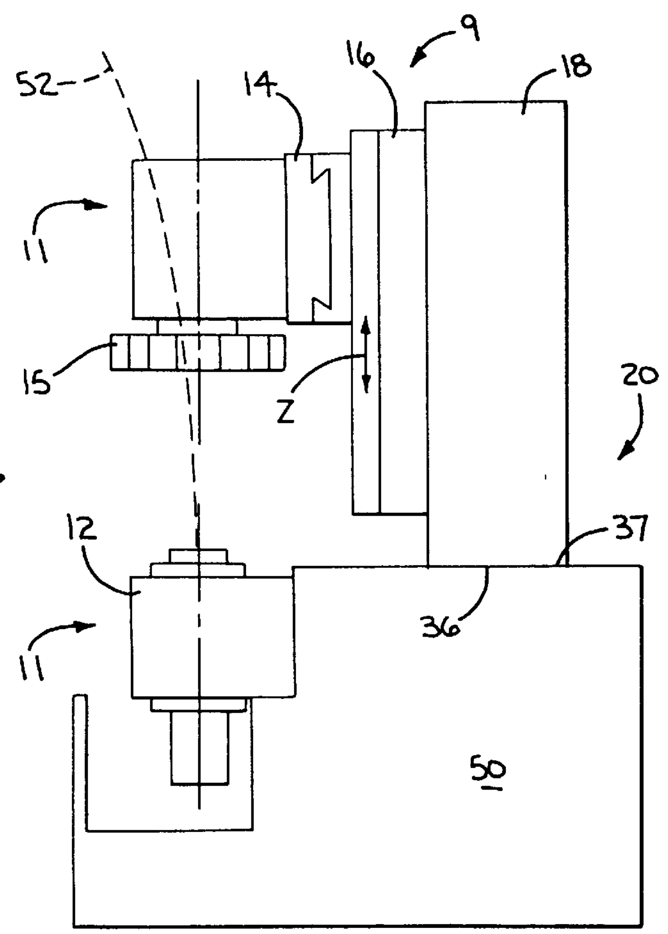
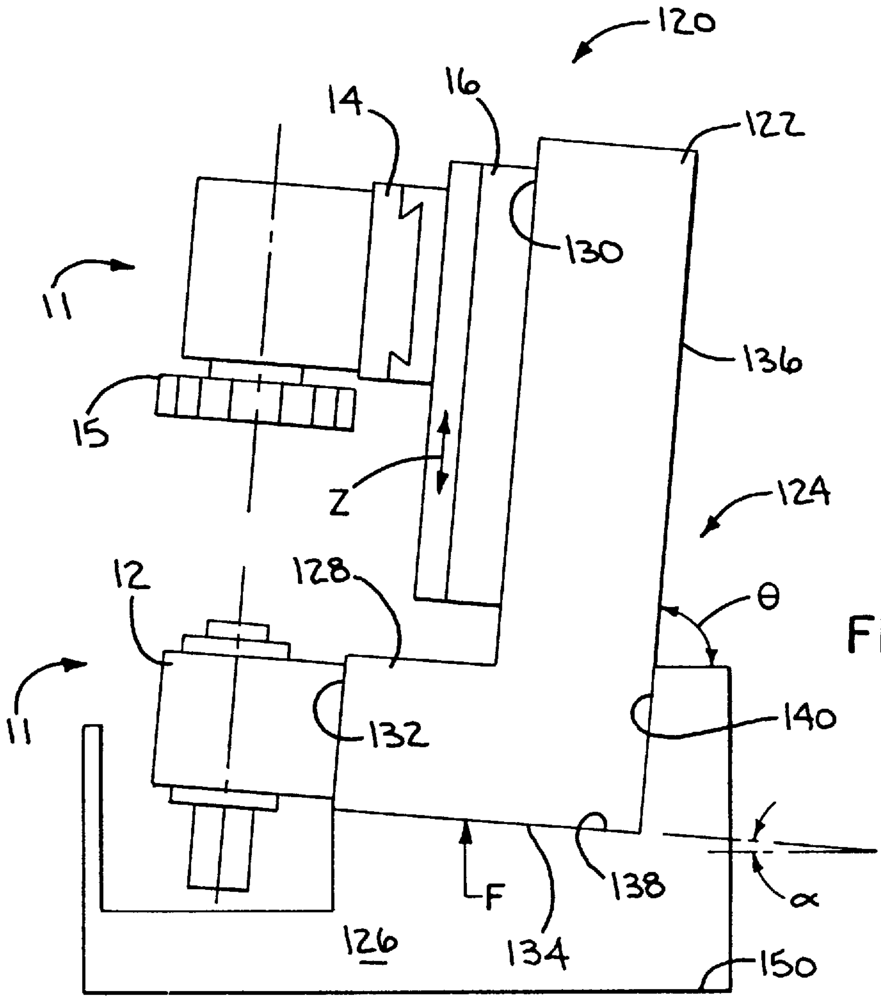


FIGURE 7



120
14
16
122
130
11
136
15
Z
124
12
128
θ
11
132
140
F
138
α
126
134
150

FIGURE 8

STRUCTURAL FRAME FOR SLANT-BED MACHINE TOOL

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of Ser. No. 08/543,061, filed Oct. 13, 1995, now abandoned.

FIELD OF THE INVENTION

This invention relates to structural frames for supporting machine tool components, and more particularly, to structural frames for slant-bed machine tools and a method for making the same.

BACKGROUND OF THE INVENTION

Structural frames for slant-bed machine tools, in particular for slant-bed CNC lathes, are well known in the prior art. Such frames position the machine tool operating components and the mount surfaces therefor at a slant angle that is neither fully vertical nor fully horizontal.

One advantage of-the slant-bed configuration is the reduction in thermal distortion of the bed structure caused by machining debris accumulation on the bed structure. By utilizing gravitational forces, the slant angle of the slant-bed facilitates an increased rate of machining debris disposal from the slant-bed, thereby reducing the amount of heat which is transferred from the machine debris to the bed.

Accuracy and high production are two of the factors considered when selecting the slant angle for a slant-bed machine tool that is intended for a particular application. Obviously, steeper slant angles tend to increase the machining debris disposal rate and therefore are preferred for high production applications that generate machining debris at a relatively high rate. However, the accuracy of the machine tool decreases as the slant angle is increased because the torque exerted on the structural frame by the cantilevered machine tool components increases.

Another factor that is considered when selecting a slant-bed machine tool is the compatibility of the slant-bed machine tool with existing production lines of the machine tool users, and in particular, with the material-handling systems of the existing production lines. The compatibility of the slant-bed machine tool is largely dependent upon the slant angle provided by the slant-bed machine tool.

Accordingly, when selecting the slant angle for a slant-bed structural frame intended for use in a particular application, there is usually a balancing between the considerations of accuracy, production and compatibility.

Typically, the structural frames for slant-bed machine tools incorporate a bed element having a machined surface for supporting the operating components of the machine tool. The bed element is normally produced from cast iron having a substantially trapezoidal cross section defined by two parallel surfaces and two nonparallel surfaces. One of the nonparallel surfaces defines the slant angle and one of the parallel sides defines either a base surface or a mating surface for attachment to a separate base element. Normally, the nonparallel surface defining the slant angle is machined on a gantry-type milling machine to produce the machined surface for supporting the operating components of the machine tool. During this machine operation, the bed element is supported in a custom jig which positions the bed element so that the nonparallel surface is parallel with the horizontal machining plane of the milling machine.

One disadvantage of this type of bed element is that a customized iron casting, with associated mold tooling, must

be provided for each of the various slant angles that may be dictated by considerations of production, accuracy, and compatibility generated by various machining applications. A slant-bed machine tool manufacturer may be limited as to the number of slant angles that are offered because of the expense associated with producing, storing, and maintaining the different sets of mold tooling required for each of the different castings.

Another disadvantage of this type of structural frame is that a separate custom jig may have to be provided for each of the different castings so that the machined surface is positioned parallel to the horizontal machining plane of the gantry-type milling machine. Again, a slant-bed machine tool manufacturer may be limited as to the number of slant angles that are offered for the slant-bed machine tools because of the expense associated with producing, maintaining, and storing each of the different jigs.

A further disadvantage of this type of structural frame is that the use of the custom jig in the machining of the component mount surface may limit the size of the milling machines that are capable of accommodating both the bed element and the custom jig. Obviously, there is an increased cost associated with purchasing larger sizes of milling machines and providing the requisite floor space.

Another disadvantage associated with this type of structural frame is that the substantially trapezoidal cross section of the bed element complicates the analysis of the thermal and stress-related distortions of the bed element. Further, because every slant angle requires a bed element having a different trapezoidal cross section, these complicated analyses must normally be completely repeated every time a slant-bed machine tool having a different slant angle is added to the product line offered by a slant-bed machine tool manufacturer.

Yet another disadvantage associate with this type of structural frame is that the assembly of the operating components onto the structural frame may be complicated by the semi-vertical orientation of the slant bed frame. Typically, special assembly tools must be made to support the weight of each of the machining components as it is being assembled onto the slant-bed frame. The special assembly tools represent additional expense.

SUMMARY OF THE INVENTION

In accordance with the present invention, a slant-bed structural frame is provided for a slant-bed machine tool. The structural frame includes a bed element having a first flat surface on which the bed element can be supported in a machining position and a second machined, flat surface that is parallel to the first surface and at least partially formed with the bed element supported on the first surface. The second surface defines a support for an operating component of the machine tool. Additionally, a base element is provided having a third surface. The third surface cooperates with a surface on the bed element to maintain the bed element in an operative position on the base element wherein the second surface is neither fully vertical nor fully horizontal.

In one form of the invention, the operative position on the base element is selected to compensate for gravity-induced deflection of the bed element.

In one form, the first flat surface of the bed element is a cast surface.

In one form, the bed element has a fourth surface and the third surface on the base element cooperates with at least one of the first surface and the fourth surface to maintain the bed element in an operative position on the base element wherein the second surface is neither fully vertical nor fully horizontal.

In one form of the invention, a structural frame kit is provided for a slant-bed machine tool whereby the frame kit provides a selection of bed slant angles. The frame kit includes a bed element having a machined, flat surface defining a support for an operating component of the machine tool. A first base element is provided having a surface cooperating with a first surface on the bed element to maintain the bed element in an operative position on the first base element wherein the machined, flat surface of the bed element is at a first slant angle that is neither fully vertical nor fully horizontal. A second base element is provided having a surface cooperating with the first surface on the bed element to maintain the bed element in an operative position on the shoe wherein the machined flat surface of the bed element is at a second slant angle that is neither fully vertical nor fully horizontal. The second slant angle provided by the second base element is different from the first slant angle provided by the first base element. The bed element is selectively-mated with only one of the first and second base elements to provide one of the first and second slant angles.

In one form of the invention, the first surface is a flat surface on which the bed element can be supported in the machining position. The machined, flat surface is parallel to the first surface and at least partially formed with the bed element supported on the first surface.

In accordance with one aspect of the present invention, a process is provided for manufacturing a structural frame for a slant-bed machine tool. The process includes the steps of forming a bed element having a first flat surface on which the bed element can be supported in a machining position; supporting the bed element on the first flat surface in the machining position; machining a second flat surface on the bed element, the second surface defining a support for an operating component of the machine tool; and forming a first base element having a third surface for maintaining the bed element in an operative position on the first base element wherein the second surface of the bed element is at a first slant angle that is neither fully vertically nor fully horizontal.

In one form of the invention, the process further includes the step of mating together the bed element and the first base element at the third surface.

In one form of the invention, the process further includes the steps of forming a second base element having a fourth surface for maintaining the bed element in an operative position on the shoe wherein the second surface of the bed element is at a second slant angle that is neither fully vertical nor fully horizontal, with the second slant angle being different from the first slant angle; and selectively mating together the bed element and one of the first base element at the third surface and the second base element at the fourth surface.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front elevation view of a conventional slant-bed machine tool;

FIG. **2** is a right side elevation view of the slant-bed tool shown in FIG. **1**;

FIG. **3** is a right side elevation view of a slant-bed machine tool having a slant-bed structural frame embodying the present invention;

FIG. **4** is a right side elevation view of another slant-bed machine tool having a slant-bed structural frame embodying the present invention;

FIG. **5** is a front elevation view of a gantry-type milling machine having a conventional slant-bed structural frame element mounted thereon for machining;

FIG. **6** is a front elevation view of a gantry-type milling machine having a slant-bed structural frame member embodying the present invention mounted thereon for machining;

FIG. **7** is a right side elevation view of a conventional, vertical-bed machine tool; and

FIG. **8** is a right side elevation view of a vertical, slant-bed machine tool having a slant-bed structural frame embodying the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A front elevation view of a prior art, slant-bed machine tool **10** is illustrated in FIG. **1** in the form of a CNC (Computer Numerical Controlled) lathe. The lathe **10** includes conventional operating components **11** that are well known to those skilled in the art. The operating components **11** include a spindle assembly **12** for rotating a workpiece (not shown), an X axis slide assembly **14**, a cutting tool turret **15**, and a Z axis slide assembly **16** for manipulating a cutting tool (not shown) relative to the workpiece as the workpiece is rotated in the spindle **12**. The spindle **12**, the turret **15**, and the X and Z axis slide assemblies **14** and **16** are mounted on and supported by a bed element **18** that is part of the structural frame **20** of the lathe **10**.

As seen in FIG. **2**, the bed element **18** of the slant-bed lathe **10** has an essentially trapezoidal cross section **30** defined by two nonparallel surfaces **32** and **34**, and two horizontally-extending parallel surfaces **36** and **38**. The nonparallel surface **32** mounts and supports the operating components **11**. The horizontal surface **36** serves to mount the bed element **18** to a base element **50** of the structural frame **20**. A slant angle Θ for the slant-bed lathe **10** is determined by the angle of intersection between the slanted surface **32** and the horizontal surface **36**.

Typically, the bed element **18** will be an iron casting, with each of the surfaces **32**, **34**, **36**, and **38** being essentially defined during the casting process.

It will be appreciated, by those skilled in the art, that a new casting along with a new set of mold tooling must be provided every time a different slant angle Θ is desired for the bed element **18** and the lathe **10**.

After the casting for the bed element **18** has been formed, the surface **32** is machined to precision form a support structure for the operating components **11**. Due to the relatively large size of the bed element **18**, the bed element **18** is typically machined on a conventional gantry-type milling machine **60**, as shown in FIG. **5**. The milling machine **60** has a gantry **62** spanning a horizontally-extending machining table **64**. The gantry **62** and the table **64** are capable of relative movement to define a first horizontal machining axis **Z1**. The gantry **62** provides support for a cutting tool spindle **66** that is translatable along a second horizontal machining axis **X1** and a vertical machining axis **Y1** relative to the gantry **62** and the table **64**. A custom jig **68** supports and positions the bed element **18** on the machining table **64** so that the surface **32** is parallel with the horizontal machine plane **X1**-**Z1** of the milling machine **60**. The jig **68** is required because the machining tables **64** of conventional gantry-type milling machines **60** are not provided with a tilting feature due to the relatively large size of the machining tables **64**.

It will be appreciated by those skilled in the art that a different custom jig **68** must be provided for machining the casting of each bed element **18** having a different slant angle Θ.

A side elevation view of a prior art, vertical-bed machine tool is illustrated in FIG. **7** in the form of a CNC lathe **9**. Similar to the lathe **10** shown in FIG. **1**, the lathe **9** includes conventional operating components **11**, such as a spindle assembly **12**, an X slide axis assembly **14**, a cutting tool turret **15**, and a Z slide axis assembly **16**. The X and Z axis slide assemblies **14,16** are mounted on and supported by a bed element **18** that is part of a structural frame **20** of the lathe **9**, while the spindle **12** is mounted on and supported directly by a base element **50** of the structural frame **20**. Similarly, a surface **36** of the bed element **18** is mounted on a horizontal surface **37** of the base element **50**.

It will be appreciated by those skilled in the art, that the cantilevered weight of the operating components **14, 15** and **16** tends to deflect the bed element **18**, thereby allowing the operating components **14, 15** and **16** to deviate from their desired position, as illustrated by the dashed center line **52** (deflection exaggerated for purpose of illustration). The accuracy of the lathe **9** is thereby decreased because the deflection inhibits the accurate alignment of a cutting tool with the workpiece.

It will also be appreciated by those skilled in the art, that the bed element **18** must be precisely located on the base **50** to provide accurate positional alignment of the spindle assembly **12** with the operating components **14, 15** and **16**. Ultimately, this requires precision matched machining of surface **36** on the bed **18** and surface **37** on the base **50**. This precision machining is expensive because the surfaces **36** and **37** are large and must be match-machined with the highest degree of accuracy. Commonly, this match-machining includes repeating the steps of hand scraping the surfaces **36** and **37**, assembling the bed **18** to the base **50**, and measuring the positional accuracy to determine if the desired accuracy for the final assembly has been achieved.

It will further be appreciated by those skilled in the art, that, to maintain the positional accuracy of the operating components **14, 15** and **16** relative to the spindle assembly **12**, the bed **18** must be prevented from shifting in any way relative to the base **50**. This further complicates the mounting of the bed **18** to the base **50** and, typically, requires a bolted joint.

Having described a conventional, prior art slant-bed machine tool and a conventional, prior art vertical-bed machine tool, the discussion will now turn to the preferred inventive embodiments.

As shown in FIG. **3**, the invention is embodied in a slant-bed machine tool **80** illustrated in the form of a CNC lathe. As with the lathe **10**, the lathe **80** includes the previously discussed conventional operating components **11**. The operating components **11** include the spindle assembly **12** and the X and Z axis slide assemblies **14** and **16**. Each of the operating components **11** is mounted to and supported by a bed element **82** of a structural frame **84**. The bed element **82** is mounted to and supported by a base element **86** of the structural frame **84**.

The bed element **82** has an essentially rectangular cross section defined by four substantially flat surfaces **88, 90, 92** and **94**. The surface **88** is formed at least partially by a machining process and serves to mount and support the operating components **11**. The surface **92** of the bed element **82** and a slanted, oblique surface **96** of the base element **86** cooperate to mount the bed element **82** to the base element **86**. As shown, but not necessarily required, another slanted, oblique surface **98** of the base element **86** cooperates with the surface **90** of the bed element **82** to assist in mounting the bed element **82** to the base element **86**. It will be appreciated

that either of the cooperating surfaces **92** and **96** or **98** and **90** may be employed by themselves to mount the bed element **82** to the base element **86**.

The bed element **82** may be secured to the base element **86** at the interface between the surfaces **92** and **96** or the interface between the surfaces **90** and **98** by any of the fastening or joining methods commonly known and employed by those skilled in the art, such as, but not limited to, threaded fasteners or epoxy.

Unlike the conventional slant-bed machine tool **10** wherein the slant angle Θ is determined by the geometry of the bed element **18**, the slant angle Θ for the slant-bed machine tool **80** is determined by the geometry of the base element **86**. More specifically, the slant angle Θ is determined by the relative angle α between the slanted surface **96** and a horizontally-extending base surface **100** of the base element **86**.

Because the bed element **82** provides the machined surface **88** which mounts and supports the operating components **11**, the stress and thermal related distortions and the precision forming of the bed element **82** are more critical to the operation of the slant-bed machine tool **80** than the forming and distortions of the base element **86**. By providing a slant-bed structural frame **84** wherein the slant angle Θ is determined by the base element **86**, rather than by the more critical bed element **82**, an entire product line of slant-bed machine tools **80** having different slant angles Θ may be provided while utilizing a standard bed element **82**. This eliminates the re-analysis of thermal and stress-related distortions required for conventional bed elements **18** because every one of the slant-bed machine tools **80** in the product line will employ the standard bed element **82**, obviously, because the stress and thermal related distortions of the base element **86** are not as critical as the distortions of the bed element **82** to the operation of the slant-bed machine tool **80**, the base element **86** does not require the same level of analysis as the bed element **82**.

Further, because a standard bed element **82** is used for the product line of slant-bed machine tools **80**, a slant-bed machine tool manufacturer will only have to provide, maintain, and store the mold tooling for a single casting for the bed element **82**, rather than the multiple sets of mold tooling required for the conventional bed elements **18**.

Assembly of the slant-bed machine tools **80** is also simplified because the operating components **11** can be assembled onto the machined surface **88** while the bed element **82** is supported on surface **90**. No special assembly tools are required because the weight of the operating components is supported by the machined surface **88**. After the operating components **11** are assembled onto the bed element **82**, the bed element **82** may be mounted onto the base element **86**.

Additionally, because the precision forming of the base element **86** is not as critical as the precision forming of bed element **82** to the operation of the machine tool **80**, the base element **86** need not be as accurately formed as the bed element **82**. Accordingly, the shoe **86** may be formed by any of the methods commonly used by those skilled in the art to form structural bases or frames for machine tools. In one such method, the base element **86** will be formed from cast iron. In another such method, the base element **86** is formed from a poured concrete/epoxy material or by a poured granite/epoxy material. Regardless of the method used in forming the base element **86**, the surfaces **96** and **98** may be utilized in their as-cast or as-poured condition without any machining of these surfaces being required.

Preferably, the bed element **82** is formed from a casting of iron. The surfaces **90** and **92** may be utilized in their as-cast condition without requiring any additional machining. However, the surface **88** must be machined to provide an accurate mount structure for mounting and supporting machine tool components **11**. To accomplish this machining, the bed element **82** is mounted on a gantry-type milling machine **110**, as seen in FIG. **6**. As with the gantry **112**-type milling machine **60** shown in FIG. **5**, the milling machine **110** includes a gantry, a machine table **114**, and a machine tool head **116**. Unlike the machining of the conventional bed element **18**, the machining of the bed element **82** does not require a jig **68** because the surface **88** is supported and located parallel to the horizontal machining plane X1-Z1 by the surface **90**.

Because a jig **68** is not required for the machining of the bed element **82**, the milling machine **110** may be smaller than the milling machine **60** used to machine a conventional bed element **18**. This results in increased accuracy for the machine surface **88** and a reduction in cost for the machining of surface **88** because the smaller milling machine **110** will typically be more accurate and less expensive than the larger milling machine **60**.

As seen in FIG. **4**, the invention is further embodied in a slant-bed lathe **80***a*, shown in the form of a CNC lathe. The lathe **80***a* incorporates the bed element **82** and all the remaining components of the lathe **80** shown in FIG. **3**, with the exception of the base element **86***a* on the structural frame **84** which is different from the base element **86**, shown in FIG. **3** in that the angle $\alpha 1$ between the surfaces **96***a* and **100***a* is different than the angle α between surface of **96** and **100**. A comparison of the slant-bed machine tools **80** and **80***a* reveals that, according to the present invention, the slant-bed machine tools **80** and **80***a* having different slant angles Θ and $\Theta 1$ are provided by mating the bed element **82** with either the base element **86** to provide the slant angle Θ or with the base element **86***a* to provide the slant angle $\Theta 1$.

Accordingly, it will be appreciated by those skilled in the art that a number of slant-bed machine tools **80**, each having a different slant angle Θ, may be provided in an advantageous manner by mating a standard bed element **82** with different base elements **86** for each slant-bed machine tool **80**.

Turning now to the embodiment shown in FIG. **8**, the invention is embodied in a vertical, slant-bed machine tool **120** illustrated in the form of a CNC lathe. As with the lathes **9**, **10** and **80**, the lathe **120** includes the previously discussed conventional operating components **11** (a spindle assembly **12**, an X slide axis assembly **14**, a cutting tool turret **15**, and a Z slide axis assembly **16**). All of the operating components **11** are mounted to and supported by a bed element **122** of a structural frame **124**. The bed element **122** is mounted to and supported by a base element **126** of the structural frame **124**.

The bed element **122** has an essentially rectangular cross section with a step **128** for mounting the spindle assembly **12**. The bed element **122** is defined by four substantially flat surfaces **130**, **132**, **134**, and **136**. The surfaces **130** and **132** are formed at least partially by a machining process and serve to mount and support the operating components **11**. The surface **134** and a slanted, oblique surface **138** of the base element **126** cooperate to mount the bed element **122** to the base element **126**. As shown, but not necessarily required, another slanted, oblique surface **140** of the base element **126** cooperates with the surface **136** to assist in mounting the bed element **122** to the base element **126**. It will be appreciated that either of the cooperating surfaces **134** and **138** or **136** and **140** may be employed by themselves to mount the bed element **122** to the base element **126**.

As with the machine tools **80** and **80***a*, the bed element **122** may be secured to the base element **126** at the interface between the surfaces **134** and **138** or the interface between the surfaces **136** and **140** by any of the fastening or joining methods commonly known and employed by those skilled in the art, such as, but not limited to, threaded fasteners or epoxy.

Unlike the conventional vertical-bed machine tool **9**, wherein the positional accuracy of the operating components **14**, **15** and **16** relative to the spindle assembly **12** is determined by the accuracy of the surfaces **36** and **37**, the positional accuracy for the slant-bed machine tool **120** is determined by the accuracy of the surfaces **130** and **132**. This is because a spindle assembly **12** is mounted to the surface **130** and the operating components **14**, **15** and **16** are mounted to the surface **132**. By mounting all of the operating components **11** on a single structural member, the bed **122**, the slant-bed machine tool **120** eliminates the need for precisely locating the bed element **122** relative to the base element **126**, thereby eliminating the requirement for precision match-machining of the bed and base elements **122** and **126**.

Further, because the bed element **122** provides both the surfaces **130** and **132** which mount and support the operating components **11**, the stress, thermal-related distortions, and precision-forming of the bed element **122** are more critical to the operation of the slant-bed machine tool **120** than the forming and distortions of the base element **126**. This allows for more flexibility in the manufacture of the base element **126** when compared to the base element **50** of the conventional vertical-bed machine tool. Accordingly, as with the base **86** of machine tool **80**, the base **126** may be formed by any of the methods commonly used by those skilled in the art to form structural bases or frames for machine tools. Regardless of the method used in forming the base element **86**, the surfaces **134**,**136** of the bed element **122** and surfaces **138**,**140** of the base element **126** may be utilized in their as-cast or as-poured condition, rather than the relatively expensive match-machined surfaces **36** and **37** of the conventional, vertical-bed machine tool **9**.

As with the machine tools **80**,**80***a*, the machine tool **120** is provided with a slant angle Θ that is determined by the relative angle α between the slanted surface **134** and a horizontally-extending base surface **150** of the base element **126**.

The slant angle Θ for the vertical, slant-bed machine tool **120** compensates for the gravity-induced deflection of the bed element **122** caused by the bending forces from the weight of the cantilevered operating components **14**, **15** and **16**. The appropriate slant angle Θ is dependent upon the weight and relative position of the operating components **14**, **15** and **16** on the bed element **122**, and the rigidity/stiffness of the bed element **122**. There are a number of ways to select an appropriate slant angle Θ. For example, the gravity-induced deflection of the bed element **122** in the absolute vertical position can be determined and then the appropriate slant angle Θ can be selected to counter this deflection. Another approach is to minimize the bending forces by aligning the combined center of gravity for the operating components **14**, **15** and **16** with the force vector F determined by the center of force between the surfaces **134** and **138**, and **136** and **140**.

I claim:

1. A structural frame kit for a slant-bed machine tool, said frame kit comprising:

a bed element having a machined, flat surface defining a support for an operating component of the machine tool;

a first base element;

first means cooperating between the first base element and the bed element for maintaining the bed element in an operative position on the first base element wherein the machined, flat surface is at a first slant angle that is neither fully vertical nor fully horizontal;

a second base element;

second means cooperating between the second base element and the bed element for maintaining the bed element in an operative position on the second base wherein the machined, flat surface is at a second slant angle that is neither fully vertical nor fully horizontal, the second slant angle being different from the first slant angle; and

the bed element being selectively mated with only one of the first and second base elements at a time to provide one of the first and second slant angles.

2. The frame kit of claim **1** wherein:

the first cooperating means comprises a first surface on the bed element and a second surface on the first base element; and

the second cooperating means comprises the first surface on the bed element and a third surface on the second base element.

3. The frame kit of claim **2** wherein the first surface is a cast surface.

4. The frame kit of claim **2** wherein the first surface is a flat surface on which the bed element can be supported in a machining position and the machined, flat surface is parallel to the first surface and at least partially formed with the bed element supported on the first surface.

5. A process for manufacturing a slant-bed structural frame for a machine tool, said process comprising the steps of:

forming a bed element having a first flat surface on which the bed element can be supported in a machining position;

supporting the bed element on the first flat surface in the machining position;

machining a second flat surface on the bed element, said second surface defining a support for an operating component of the machine tool;

forming a first base element having a third surface for maintaining the bed element in an operative position on the first base element wherein the second surface of the bed element is at a first slant angle that is neither fully vertical nor fully horizontal when the bed element and the first base element are mated together; and

forming a second base element having a fourth surface for maintaining the bed element in an operative position on the base wherein the second surface of the bed element is at a second slant angle that is neither fully vertical nor fully horizontal, the second slant angle being different from the first slant angle; and

selectively mating together the bed element and one of the first base element at the third surface and the second element at the fourth surface.

6. A structural frame combination for a slant-bed machine tool, said combination comprising:

a bed element having a first flat surface on which the bed element can be supported in a machining position and a second machined, flat surface that is parallel to the first surface and at least partially formed with the bed element supported on the first surface,

said second surface defining a support for an operating component of the machine tool;

a base element;

means cooperating between the base element and the bed element for maintaining the bed element in an operative position on the base element wherein the second surface is at a first slant angle that is neither fully vertical nor fully horizontal, the operative position being selected to compensate for gravity-induced deflection of the bed element; a second base element and a second means cooperating between the second base element and the bed element for maintaining the bed element in an operating position on the base element wherein the second surface is at a second slant angle that is not fully vertical nor fully horizontal, the second slant angle being different from the first slant angle; and wherein the bed element is selectively mated with one of the first and second base elements at a time to provide one of the first and second slant angles.

7. The combination of claim **6**, wherein the first flat surface is a cast surface.

8. The combination of claim **6** wherein the cooperating means comprises the first surface on the bed element and a third surface on the base element.

9. The combination of claim **6** wherein the cooperating means comprises a third surface on the base element and at least one of the first surface and a fourth surface on the bed element.

10. The combination of claim **6** wherein:

the first cooperating means comprises the first surface on the bed element and a third surface on the first base element; and

the second cooperating means comprises the first surface of the bed element and a fourth surface on the second base element.

* * * * *

US005842396A

United States Patent [19]

Miyano

[11] **Patent Number: 5,842,396**

[45] **Date of Patent: Dec. 1, 1998**

[54] **STRUCTURAL FRAME FOR A MACHINE TOOL**

[76] Inventor: **Toshiharu Tom Miyano**, c/o Miyano Machinery USA Inc., 940 N. Central Ave., Wood Dale, Ill. 60191

[21] Appl. No.: **908,454**

[22] Filed: **Aug. 7, 1997**

[51] **Int. Cl.**[6] **B23B 17/00**

[52] **U.S. Cl.** **82/149**; 82/901; 408/234

[58] **Field of Search** 82/149, 117, 901; 408/234, 235, 236, 237; 409/236, 240, 241

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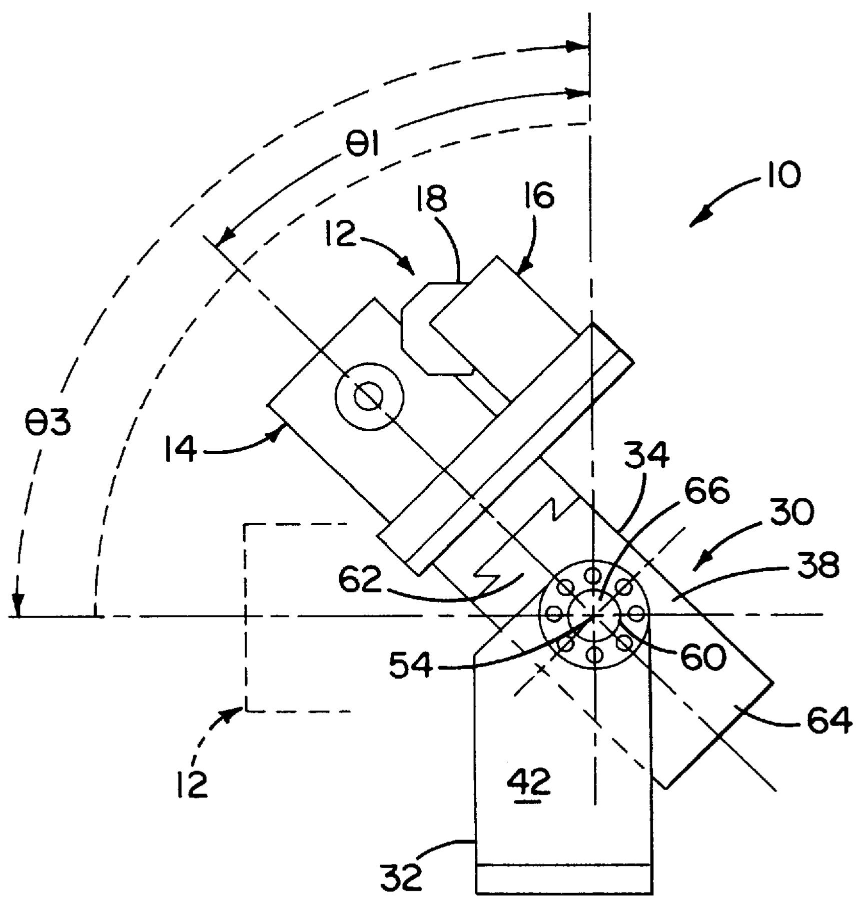
Primary Examiner—Andrea L. Pitts
Assistant Examiner—Henry W.H. Tsai
Attorney, Agent, or Firm—Wood, Phillips, VanSanten, Clark & Mortimer

[57] **ABSTRACT**

A structural frame is provided for a machine tool including a tool holder and a workpiece holder for holding the workpiece as the workpiece is machined by a cutting tool held in the tool holder. The frame includes a base, a bed for supporting a tool holder and a workpiece holder as the tool holder and the workpiece holder cooperate to machine a workpiece, and structure cooperating between the bed and the base for simultaneous movement of the bed, a tool holder supported by the bed and a workpiece holder supported by the bed relative to the base between (a) a first operative position where the tool holder and the workpiece holder are supported by the bed at a first angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece, and (b) a second operative position where the tool holder and the workpiece holder are supported by the bed at a second angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece.

9 Claims, 2 Drawing Sheets



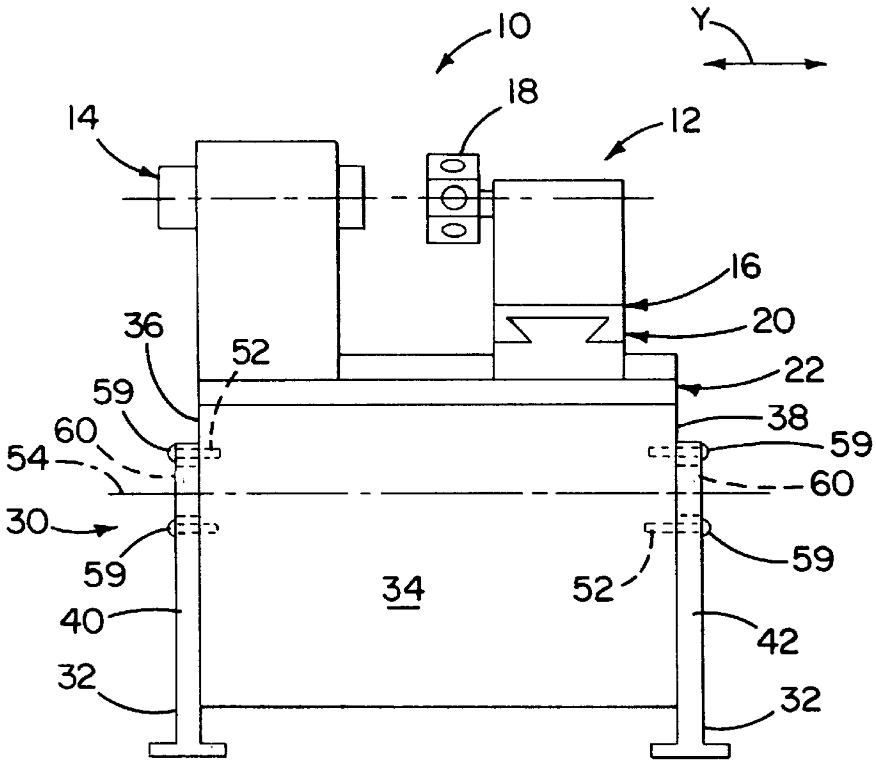

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FIG. 1

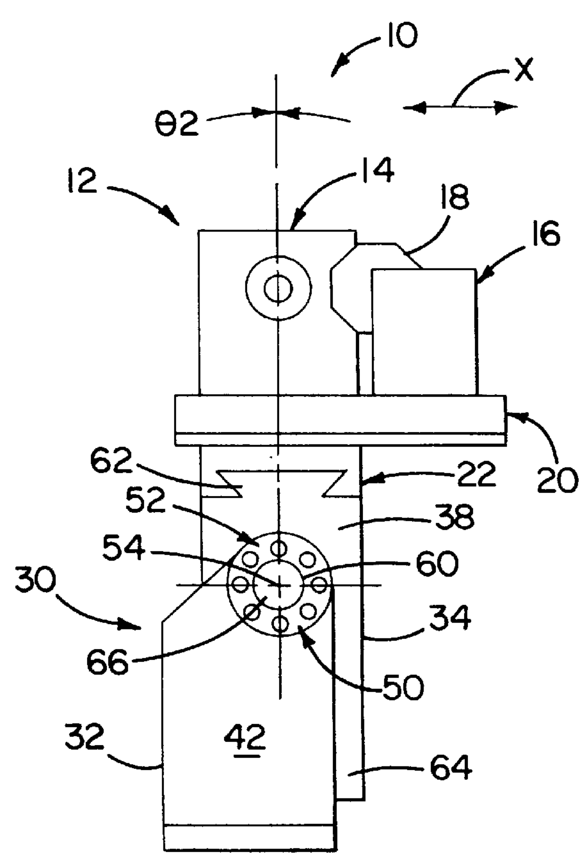
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FIG. 2

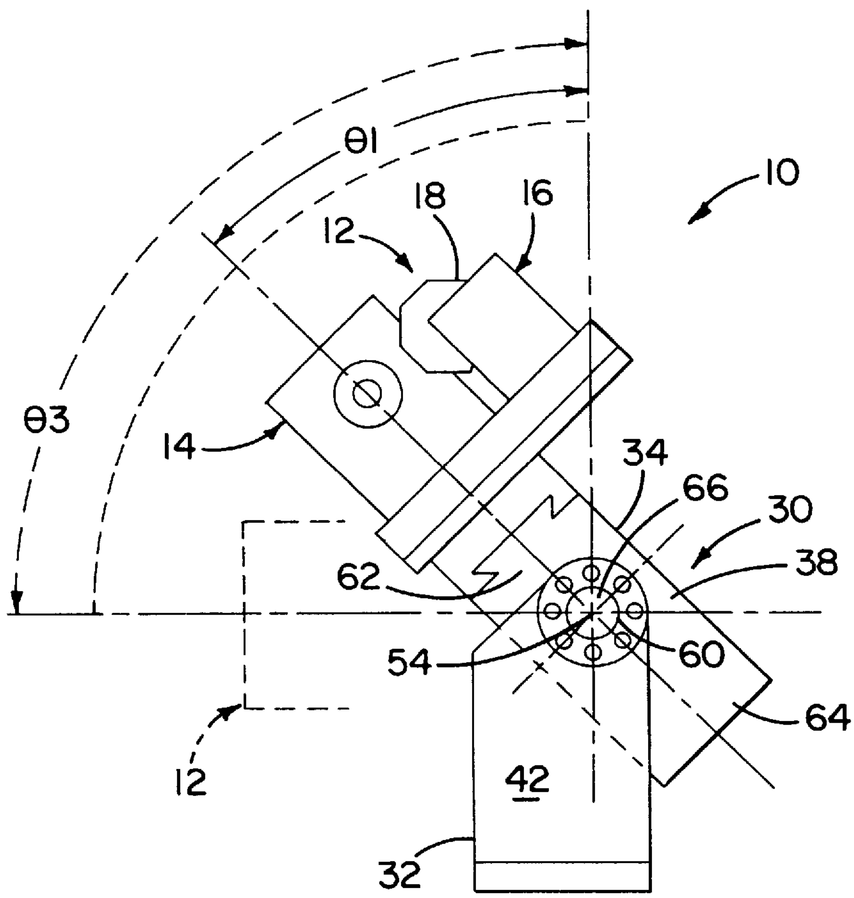

FIG. 3

STRUCTURAL FRAME FOR A MACHINE TOOL

FIELD OF THE INVENTION

This invention relates to structural frames for supporting machine tool components, and more particularly, to structural frames for slant-bed machine tools and a method for making the same.

BACKGROUND ART

Structural frames for slant-bed machine tools, in particular for slant-bed CNC lathes, are well known in the prior art. Such frames allow positioning of the machine tool operating components and the mount surfaces therefor at a slant angle that is neither fully vertical nor fully horizontal.

One advantage of the slant-bed configuration is the reduction in thermal distortion of the bed structure caused by machining debris accumulation on the bed structure. By utilizing gravitational forces, the slant angle of the slant-bed facilitates an increased rate of machining debris disposal from the slant-bed, thereby reducing the amount of heat which is transferred from the machine debris to the bed.

Accuracy and high production are two of the factors considered when selecting the slant angle for a slant-bed machine tool that is intended for a particular application. Obviously, steeper slant angles tend to increase the machining debris disposal rate and therefore are preferred for high production applications that generate machining debris at a relatively high rate. However, the accuracy of the machine tool may decrease as the slant angle is increased because the torque exerted on the structural frame by the cantilevered machine tool components increases.

Another factor that is considered when selecting a slant-bed machine tool is the compatibility of the slant-bed machine tool with existing production lines of the machine tool users, and in particular, with the material-handling systems of the existing production lines. The compatibility of the slant-bed machine tool is largely dependent upon the slant angle provided by the slant-bed machine tool.

Accordingly, when selecting the slant angle for a slant-bed structural frame intended for use in a particular application, there is usually a balancing between the considerations of accuracy, production and compatibility.

Typically, the structural frames for slant-bed machine tools incorporate a bed element having at least one machined surface for supporting the operating components of the machine tool. The bed element is normally produced from cast iron having a substantially trapezoidal cross section defined by two parallel surfaces and two nonparallel surfaces. One of the nonparallel surfaces defines the slant angle and one of the parallel sides defines either a base surface or a mating surface for attachment to a separate base element. Normally, the nonparallel surface defining the slant angle is machined on a gantry-type milling machine to produce the machined surface for supporting the operating components of the machine tool. During this machine operation, the bed element is supported in a custom jig which positions the bed element so that the nonparallel surface is parallel with the horizontal machining plane of the milling machine.

One disadvantage of this type of bed element is that a customized iron casting, with associated mold tooling, must be provided for each of the various slant angles that may be dictated by considerations of production, accuracy, and compatibility generated by various machining applications. A slant-bed machine tool manufacturer may be limited as to the number of slant angles that are offered because of the expense associated with producing, storing, and maintaining the different sets of mold tooling required for each of the different castings.

Another disadvantage of this type of structural frame is that a separate custom jig may have to be provided for each of the different castings so that the machined surface is positioned parallel to the horizontal machining plane of the gantry-type milling machine. Again, a slant-bed machine tool manufacturer may be limited as to the number of slant angles that are offered for the slant-bed machine tools because of the expense associated with producing, maintaining, and storing each of the different jigs.

A further disadvantage of this type of structural frame is that the use of the custom jig in the machining of the component mount surface may limit the size of the milling machines that are capable of accommodating both the bed element and the custom jig. Obviously, there is an increased cost associated with purchasing larger sizes of milling machines and providing the requisite floor space.

Another disadvantage associated with this type of structural frame is that the substantially trapezoidal cross section of the bed element may complicate the analysis of the thermal and stress-related distortions of the bed element. Further, because every slant angle requires a bed element having a different trapezoidal cross section, these complicated analyses must normally be completely repeated every time a slant-bed machine tool having a different slant angle is added to the product line offered by a slant-bed machine tool manufacturer.

Yet another disadvantage associate with this type of structural frame is that the assembly of the operating components onto the structural frame may be complicated by the semi-vertical orientation of the slant bed frame. Typically, special assembly tools must be made to support the weight of each of the machining components as it is being assembled onto the slant-bed frame. The special assembly tools represent additional expense.

SUMMARY OF THE INVENTION

In accordance with the present invention, a structural frame is provided for a machine tool including a tool holder and a workpiece holder for holding the workpiece as the workpiece is machined by a cutting tool held in the tool holder. The frame includes a base, a bed for supporting a tool holder and a workpiece holder as the tool holder and the workpiece holder cooperate to machine a workpiece, and structure cooperating between the bed and the base for simultaneous movement of the bed, a tool holder supported by the bed and a workpiece holder supported by the bed relative to the base between (a) a first operative position where the tool holder and the workpiece holder are supported by the bed at a first angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece, and (b) a second operative position where the tool holder and the workpiece holder are supported by the bed at a second angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece.

In one form, the cooperating structure includes a first fastener hole pattern on the base and a second fastener hole pattern on the bed. The first and second fastener hole patterns are aligned in both the first position and the second position.

In one form, the cooperating structure includes structure for mounting the bed on the base for pivotable movement between the first and second positions.

In one form of the invention, a structural frame is provided for a machine tool including a tool holder and a workpiece holder for holding the workpiece as the workpiece is machined by a cutting tool held in the tool holder. The frame includes a base and a bed for supporting a tool holder and a workpiece holder as the tool holder and the workpiece holder cooperate to machine a workpiece. The base includes a first fastener hole pattern and the bed includes a second fastener hole pattern that is alignable with the first fastener hole pattern to mount the bed on the base selectively in each of (a) a first operative position where a tool holder and a workpiece holder are supported by the bed at a first angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece, and (b) a second operative position where a tool holder and a workpiece holder are supported by the bed at a second angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece.

In one form, the base comprises a first stanchion spaced from a second stanchion, and the first fastener hole pattern is located on the first stanchion.

In one form, the frame further includes structure cooperating between the bed and the stanchions for simultaneous movement of the bed, a tool holder supported by the bed, and a workpiece holder supported by the bed between the first and second positions.

In one form of the invention, a structural frame is provided for a machine tool including a tool holder and a workpiece holder for holding the workpiece as the workpiece is machined by a cutting tool held in the tool holder. The frame includes a base, and a bed for supporting a tool holder and a workpiece holder. The bed is pivotable on the base about an axis and has a center of gravity located relative to the axis to counterbalance the moment about the axis created by a tool holder and a workpiece holder supported on the bed.

In one form, a process for manufacturing a structural frame for a machine tool is provided. The process includes the steps of forming a base having a first fastener hole pattern; forming a bed having structure for supporting a tool holder and a workpiece holder as the tool holder and the workpiece holder cooperate to machine a workpiece; forming a second fastener hole pattern on the bed that is alignable with the first fastener hole pattern selectively in each of (a) a first operative position where a tool holder and a workpiece holder are supported by the bed at a first angular orientation relative to the base as the tool holder and workpiece holder cooperate to machine a workpiece, and (b) a second operative position where a tool holder and a workpiece holder are supported by the bed at a second angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece; aligning the first and second fastener hole patterns in one of the first and second positions; and fastening the bed to the base in one of the first and second positions using the fastener hole patterns.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front elevation view of a machine tool having a slant bed structural frame embodying the present invention;

FIG. **2** is a right side elevation view of the machine tool shown in FIG. **1** with the structural frame in a first orientation, with a portion of the frame broken away to reveal hidden elements; and

FIG. **3** is a right side elevation view of the machine tool shown in FIG. **1** showing the structural frame in a second orientation, with a portion of the frame broken away to reveal hidden elements.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As shown in FIGS. **1** and **2**, the invention is embodied in a machine tool **10** illustrated in the form of a CNC lathe. The lathe **10** includes conventional operating components **12** that are well known to those skilled in the art. The operating components **12** include a workpiece holder **14** in the form of a spindle assembly for rotating a workpiece (not shown), and a cutting tool holder **16** shown in the form of a tool turret assembly **18** carried on X and Y axis slide assemblies **20** and **22**. The operating components **12** are mounted on and supported by a structural frame **30** that includes a base **32** and a bed element **34**. More specifically, the bed **34** is mounted on and supported by the base **32**, and the operating components **12** are mounted on and supported by the bed element **34** as the operating components cooperate to machine a workpiece.

As best seen in FIG. **1**, the bed element **34** has a pair of spaced end surfaces **36** and **38**. The base **32** is formed by a pair of stanchions **40** and **42** located adjacent the end surfaces **36** and **38**, respectively. Preferably, the bed **34** is an iron casting similar to the iron castings of conventional beds. The stanchion arms **40** and **42** are steel or other suitable cast metal.

As best seen in FIG. **2**, a first fastener hole pattern **50** is formed in the stanchion **42** and a second fastener hole pattern **52** is formed in the end surface **36** to match the first fastener hole pattern. Preferably, an identical set of fastener hole patterns are provided on the stanchion **40** and the end surface **36**. The patterns **50** and **52** are symmetrical about a horizontally extending central axis **54**, and are alignable in a plurality of operative positions as they are rotated guidingly relative to each other about the axis **54**.

Thus, as seen in FIG. **3**, the bed **34** supports the operating components **12** in a first operative position at a first angle $\theta 1$ (approximately 45°) relative to the base **32** as the operating components cooperate to machine a workpiece. As seen in FIG. **2**, the bed **34** supports the operating components **12** in a second operative position at a second angle $\theta 2$ (approximately 0°) relative to the base **32** as the operating components cooperate to machine a workpiece. As seen in FIG. **3**, the structural frame **30** can provide a third operative position (shown hidden) wherein the bed **34** supports the operating components at a third angle $\theta 3$ (approximately to 90°) relative to the base **32** as the operating components cooperate to machine a workpiece. It should be understood from the foregoing that the number of operative positions provided by the structural frame **30** is dependent wholly upon the number and spacing of the holes in the hole patterns **50** and **52**.

As seen in FIG. **1**, the base **32** and the bed **34** are maintained relative to each other in any one of the operative positions by suitable fasteners **59** directed through the aligned hole patterns **50** and **52**. In this regard, it should be understood that the hole patterns **50** and **52** could be defined by through holes that are suitable for receiving either a nut and bolt combination or a rivet. Alternatively, one of the hole patterns **50** and **52** could be defined by through holes and the other of the hole patterns could be defined by threaded holes suitable for receiving a threaded fastener, such as a shoulder bolt.

Preferably, the structural frame **30** further includes pivot mounts **60** for mounting the bed **34** to the stanchions **40** and

42 to allow pivoting movement between each of the operative positions. This simplifies the procedure required to modify the structural frame **30** from one operative position to another.

As best seen in FIGS. **2** and **3**, the bed element **34** has an essentially rectangular cross-section that includes an upper structure **62** for mounting the operating components **12** and a lower structure **64** which provides a mass to counterbalance the mass of the operating components **12**. More specifically, the fastener hole patterns **50** and **52** define a centroid **66** located at the axis **54**. Preferably, the lower structure **64** is designed to have a sufficient mass to locate the center of gravity for the bed element **34** relative to the centroid **66** so that the combined center of gravity for the bed element **34** and the operating components **12** is approximately centered at the centroid **66** when the operating components **12** are mounted on the bed element **34**. This serves to counterbalance the moment about the centroid **66** created by the operating components **12**, thereby lowering stresses in the fastener **59** and the structure surrounding fastener hole patterns **50** and **52**.

By providing a structural frame **30** capable of providing several different operative positions at several different angular orientations relative to the base **32**, the structural frame **30** can be used to replace an entire product line of conventional slant bed machine tools. This eliminates the need for creating and maintaining the plurality of customized iron castings, with associated mold tooling, that must be provided for a product line of conventional slant bed machine tools. This also eliminates the need to produce and maintain a plurality of separate custom jigs that must be provided for a product line of conventional slant bed machine tools. Further, this eliminates the need for repetitive thermal and stress analyses that is required for a product line of conventional slant bed machine tools.

Further, assembly of the machine tool **10** is simplified in comparison to conventional slant bed machine tools because the operating components **12** can be assembled onto the bed **34** while the bed **34** is positioned with a slant angle θ equal to zero, as shown in FIG. **2**. This eliminates the need for special assembly tools because the weight of the operating components **12** is supported on the bed **34**. After the operating components **12** are assembled onto the bed **34**, the bed may be reoriented to a different operating position having a different slant angle θ, as shown in FIG. **3**.

It should also be appreciated that because the bed element **34** has an essentially rectangular cross-section, the bed element **34** may be machined without the use of a custom jig as is required for conventional slant bed machine tools. Further, because a jig is not required for the machining of the bed element **34**, the milling machine used to mill the bed element may be smaller than the milling machine used to machine a bed element for a conventional slant bed machine tool. This permits increased accuracy and potential reduction in cost for the machining of the bed **34** because the smaller milling machine would typically be more accurate and less expensive than a larger milling machine.

I claim:

1. A structural frame for a machine tool, the machine tool including a tool holder and a workpiece holder for holding a workpiece as the workpiece is machined by a cutting tool held in the tool holder, said frame comprising:

a base;

a bed for supporting a tool holder and a workpiece holder as the tool holder and the workpiece holder cooperate to machine a workpiece; and

means cooperating between the bed and the base for simultaneous movement of the bed, a tool holder supported by the bed and a workpiece holder supported by the bed relative to the base between

a first operative position where the tool holder and the workpiece holder are supported by the bed at a first angular orientation relative to the base as the tool holder and workpiece holder cooperate to machine a workpiece, and

a second operative position where the tool holder and the workpiece holder are supported by the bed at a second angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece.

2. The frame of claim **1** wherein said cooperating means comprises a first fastener hole pattern on the base and a second fastener hole pattern on the bed, the first and second fastener hole patterns being aligned in both the first position and the second position.

3. The frame of claim **1** wherein said cooperating means comprises means for mounting the bed on the base for pivotable movement between the first and second positions.

4. The frame of claim **1** in combination with a workpiece holder and a tool holder of a machine tool.

5. A structural frame for a machine tool, the machine tool including a tool holder and a workpiece holder for holding a workpiece as the workpiece is machined by a cutting tool held in the tool holder, said frame comprising:

a base including a first fastener hole pattern; and

a bed for supporting a tool holder and a workpiece holder as the tool holder and the workpiece holder cooperate to machine a workpiece, the bed including a second fastener hole pattern that is alignable with the first fastener hole pattern to mount the bed on the base selectively in each of

a first operative position where a tool holder and a workpiece holder are supported by the bed at a first angular orientation relative to the base as the tool holder and workpiece holder cooperate to machine a workpiece, and

a second operative position where a tool holder and a workpiece holder are supported by the bed at a second angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece.

6. The frame of claim **5** wherein the base further comprises a first stanchion spaced from a second stanchion, and wherein the first fastener hole pattern is on the first stanchion.

7. The structural frame of claim **6** further comprising means cooperating between the bed and the stanchions for simultaneous movement of the bed, a tool holder supported by the bed, and a workpiece holder supported by the bed between the first and second positions.

8. A structural frame for a machine tool, the machine tool including a tool holder and a workpiece holder for holding the workpiece as the workpiece is machined by a cutting tool held in the tool holder, said frame comprising:

a base; and

a bed for supporting a tool holder and a workpiece holder, the bed pivotable guidingly relative to the base about a predetermined axis, the bed having a center of gravity located relative to said axis to counterbalance a moment about said axis created by a tool holder and a workpiece holder supported on the bed.

9. A process for manufacturing a structural frame for a machine tool, the machine tool including a tool holder and

a workpiece holder for holding a workpiece as the workpiece is machined by a cutting tool held in the tool holder, said process comprising the steps of:

forming a base having a first fastener hole pattern;

forming a bed having structure for supporting a tool holder and a workpiece holder as the tool holder and the workpiece holder cooperate to machine a workpiece;

forming a second fastener hole pattern on the bed that is alignable with the first fastener hole pattern selectively in each of

a first operative position where a tool holder and a workpiece holder are supported by the bed at a first angular orientation relative to the base as the tool

holder and workpiece holder cooperate to machine a workpiece, and

a second operative position where a tool holder and a workpiece holder are supported by the bed at a second angular orientation relative to the base as the tool holder and the workpiece holder cooperate to machine a workpiece;

aligning the first and second fastener hole patterns in one of the first and second positions; and

fastening the bed to the base in the one of the first and second positions using the fastener hole patterns.

* * * * *

US005911803A

United States Patent [19]

Miyano

[11] **Patent Number: 5,911,803**

[45] **Date of Patent: Jun. 15, 1999**

[54] **SYSTEM AND METHOD FOR DELIVERING ELONGATE WORKPIECES TO A POINT OF USE**

[76] Inventor: **Toshiharu Tom Miyano**, 50 Dundee La., Barrington Hills, Ill. 60010

[21] Appl. No.: **08/924,597**

[22] Filed: **Sep. 4, 1997**

[51] **Int. Cl.**[6] **B23B 3/00**; B23B 13/00; B23B 17/00

[52] **U.S. Cl.** **82/1.11**; 82/124; 82/125; 82/126; 82/127; 414/18; 414/751

[58] **Field of Search** 82/1.11, 124, 125, 82/126, 127; 414/15, 17, 18, 680, 751

[56] **References Cited**

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Primary Examiner—Andrea L. Pitts
Assistant Examiner—Toan Le
Attorney, Agent, or Firm—Wood, Phillips, Van Santen, Clark & Mortimer

[57] **ABSTRACT**

A system for delivering elongate workpieces to a point of use. The delivering system has a first storage unit for a supply of a first type of elongate workpiece, a second storage unit for a supply of a second type of elongate workpiece, a pickup unit for selectively picking up elongate workpieces one-by-one from the first and second storage units, and a guide system for guidingly moving the pickup unit with a workpiece picked up thereby to a predetermined transfer location.

22 Claims, 4 Drawing Sheets

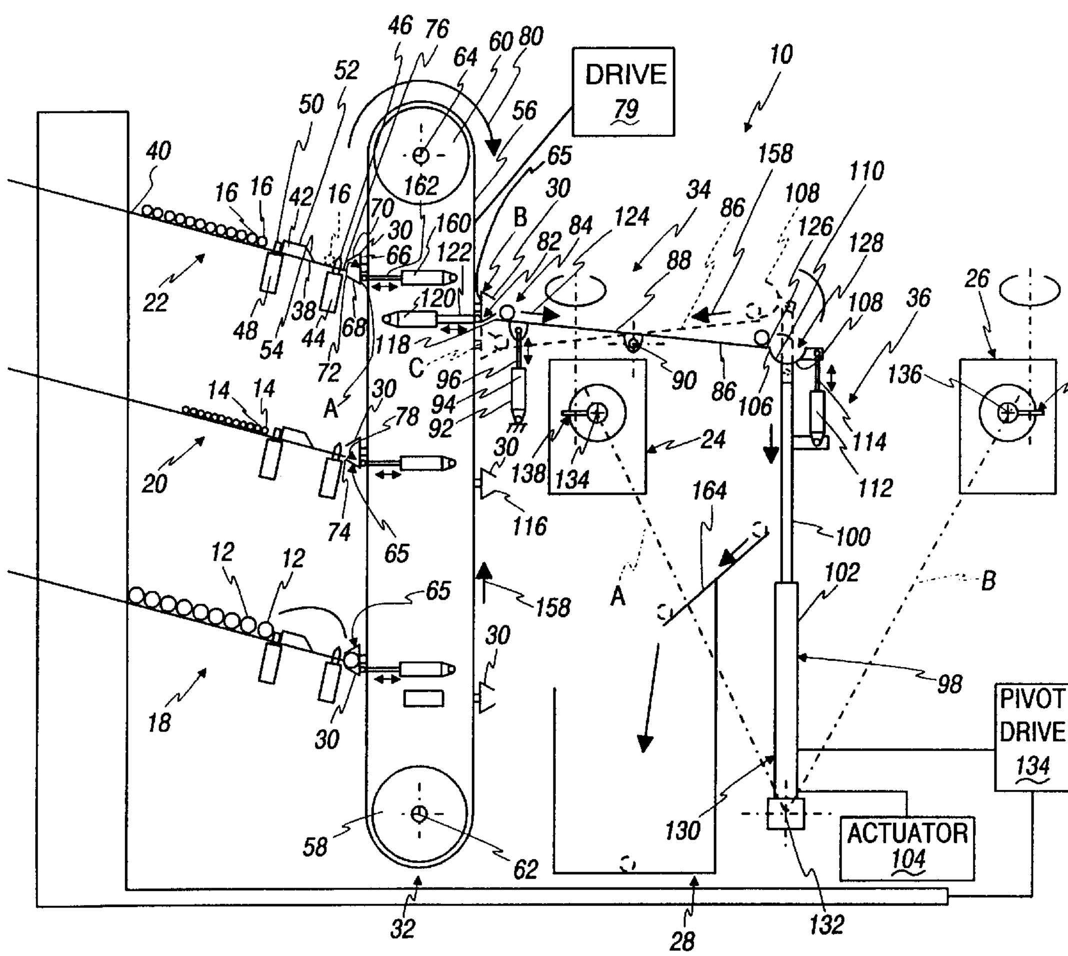
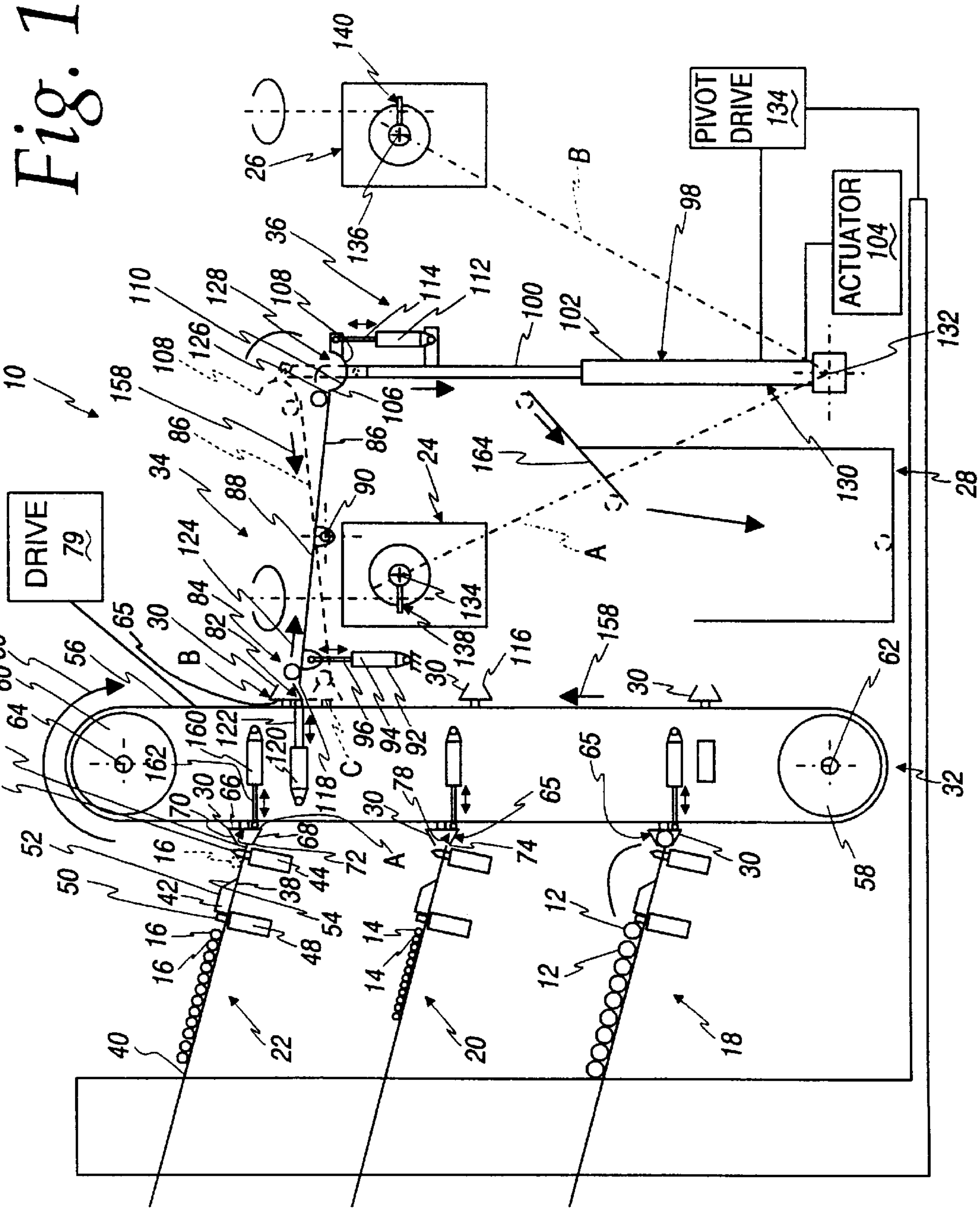


Fig. 1



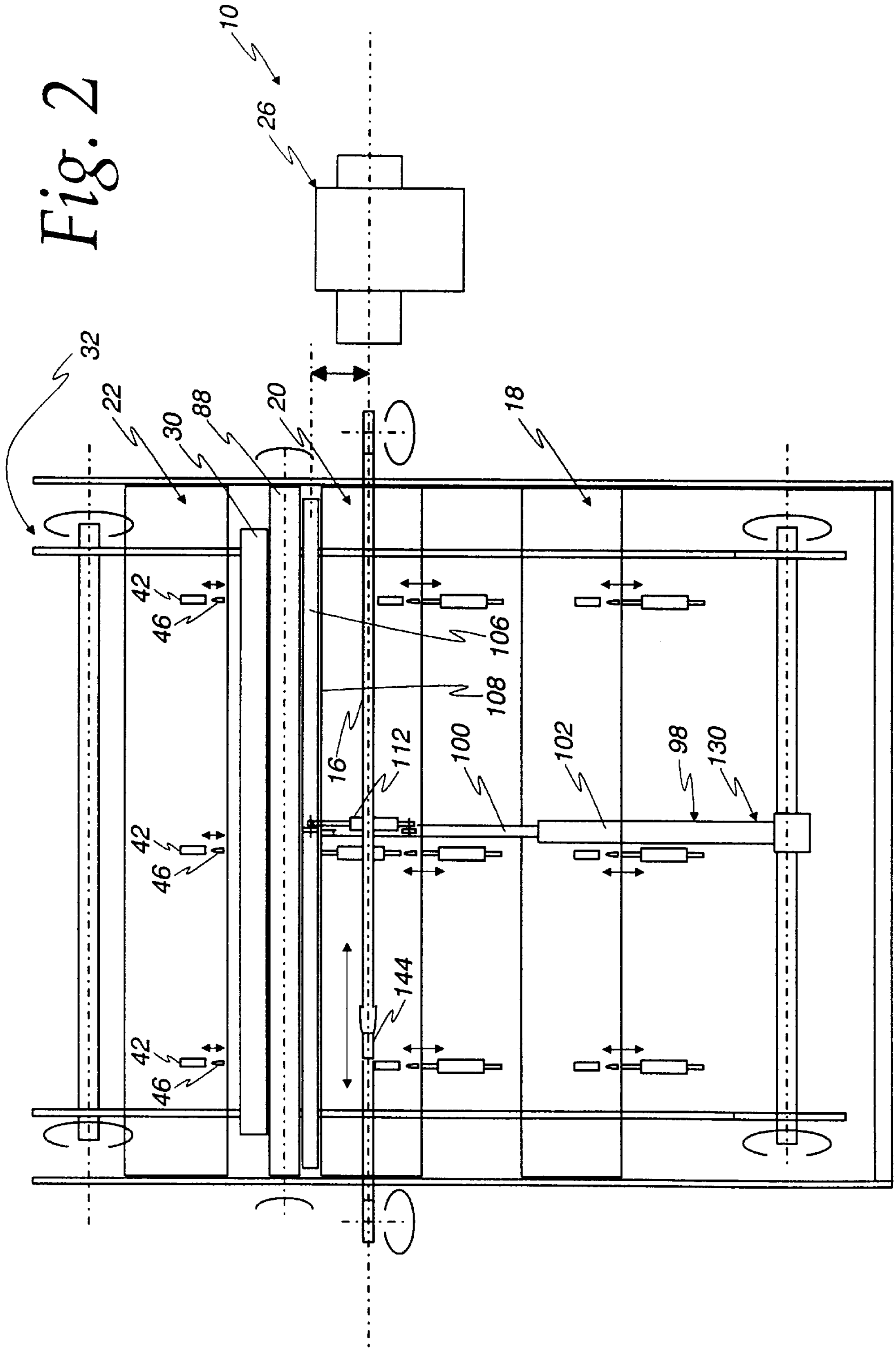


Fig. 2

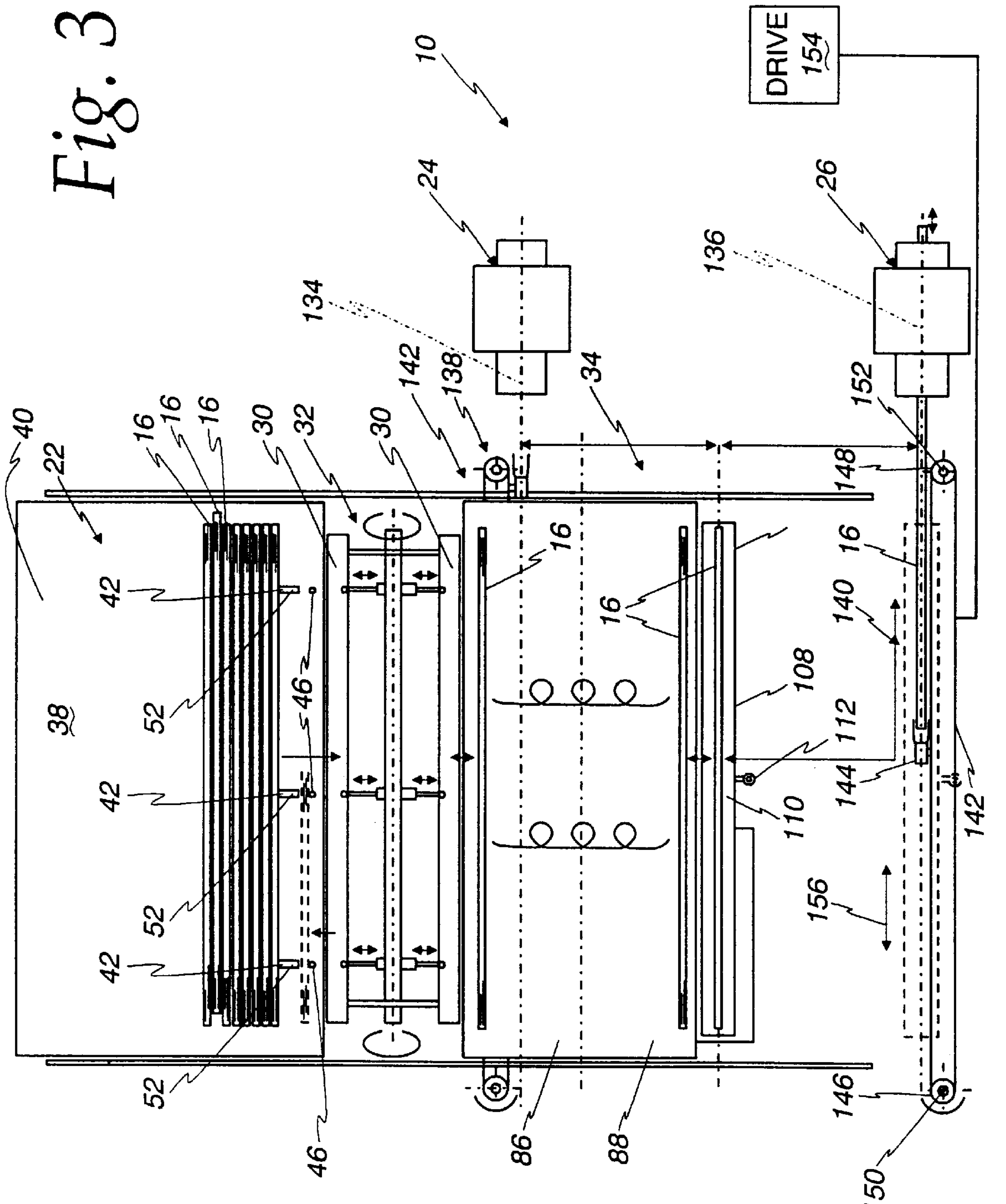


Fig. 3

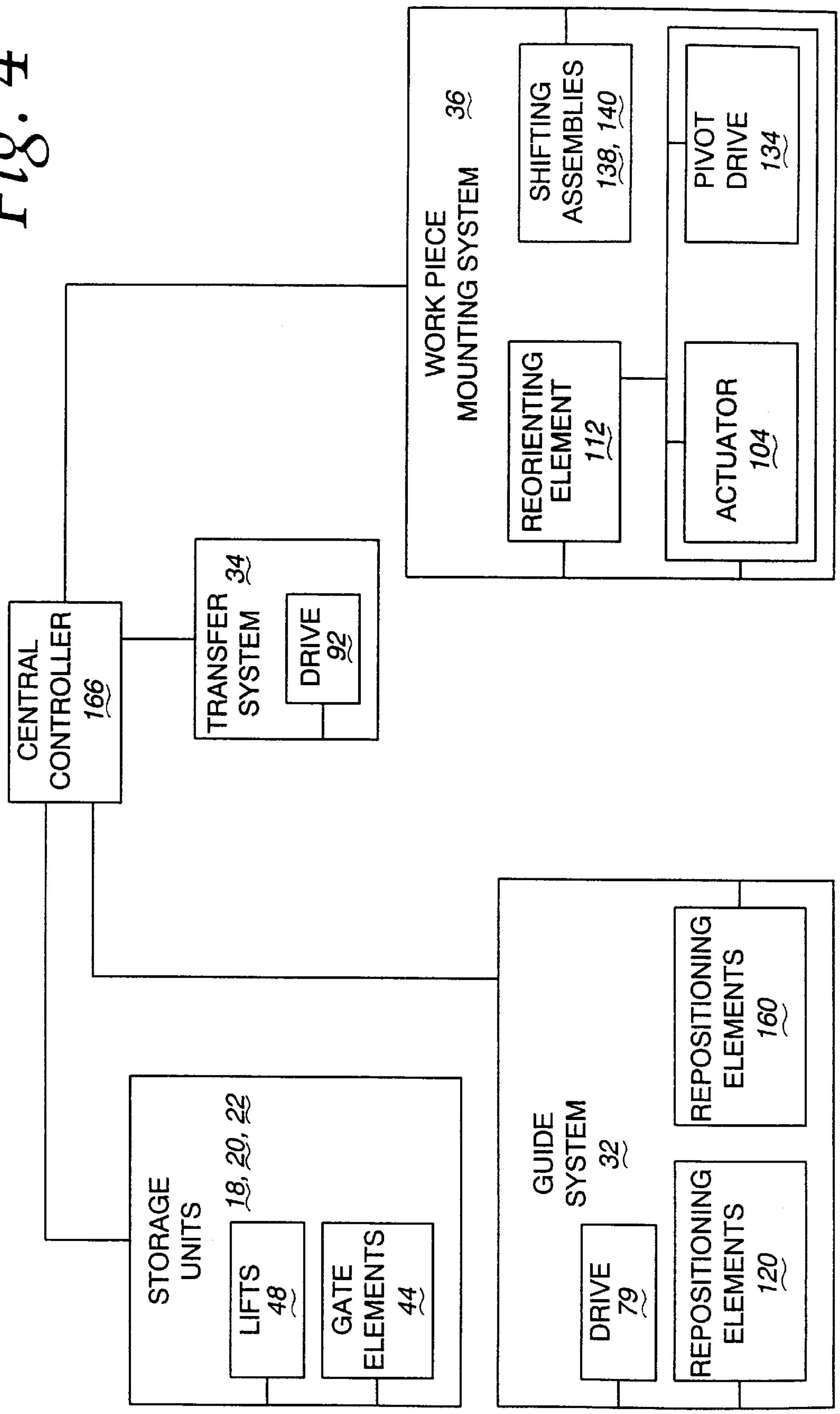

CENTRAL CONTROLLER 166
TRANSFER SYSTEM 34
DRIVE 92
WORK PIECE MOUNTING SYSTEM 36
SHIFTING ASSEMBLIES 138, 140
REORIENTING ELEMENT 112
PIVOT DRIVE 134
ACTUATOR 104
STORAGE UNITS 18, 20, 22
LIFTS 48
GATE ELEMENTS 44
GUIDE SYSTEM 32
DRIVE 79
REPOSITIONING ELEMENTS 120
REPOSITIONING ELEMENTS 160

Fig. 4

SYSTEM AND METHOD FOR DELIVERING ELONGATE WORKPIECES TO A POINT OF USE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to workpiece handling systems and, more particularly, to a system for handling elongate workpieces and a method of using such a system.

2. Background Art

It is known to automatically deliver elongate workpieces to a tool which performs a processing operation on the workpiece. It is known, for example, to automatically deliver elongate workpieces to a turning lathe. Typically, these delivery systems are designed to handle a single configuration workpiece. In the event that a workpiece having a configuration not compatible with the delivery system is to be processed by the tool, it is generally necessary to either manually control the workpiece or provide a second delivery system to work in conjunction with the first described delivery system.

It is desirable to design such automated delivery systems to be constructed economically and to allow them to operate quickly with minimal operator intervention and inconvenience.

SUMMARY OF THE INVENTION

In one form of the invention, a system is provided for delivering elongate workpieces to a point of use. The delivering system has a first storage unit for a supply of a first type of elongate workpiece, a second storage unit for a supply of a second type of elongate workpiece, a pickup unit for selectively picking up elongate workpieces one-by-one from the first and second storage units, and a guide system for guidingly moving the pickup unit with a workpiece picked up thereby to a predetermined transfer location.

The first storage unit may have an inclined surface for guiding workpieces moving under gravitational forces towards a ready position from which a workpiece can be transferred to the pickup unit.

The first storage unit may further have a blocking element against which a workpiece moving downwardly on the inclined surface abuts and a lift for selectively directing a workpiece abutted to the blocking element upwardly to allow movement of the working element past the blocking element to the ready position.

The first storage unit may include a gate element that is placeable selectively in a) an extended position wherein the gate element blocks a workpiece in the ready position; and b) a release position wherein the workpiece in the ready position is allowed to move to the pickup unit.

The pickup unit may include at least one carrier with a receptacle for a workpiece, with the carrier being movable through a guide system between a) a pickup position wherein a workpiece can be transferred from the first storage unit to the carrier receptacle and b) a delivery position at the transfer location.

The guide system may include a member that moves around a pair of spaced pulleys in an endless path, with the carrier being attached to the member to follow movement of the member to thereby move between the pickup and delivery positions.

The delivery system may be provided in combination with a tool for performing a processing step on a workpiece. A workpiece mounting system may be provided for conveying a workpiece from the transfer location into an operative state on the tool.

First and second tools can be provided for performing separate processing steps on a workpiece. The workpiece mounting system can convey a workpiece from the transfer location into an operative state selectively on either of the first and second tools.

The mounting system may include a seat member for supporting a workpiece and a transfer system for moving a workpiece at the transfer location to a supported position on the seat member.

The transfer system may include a surface that is inclined downwardly from the transfer location towards the seat member to cause a workpiece to be guided under its own weight in movement between the transfer location and the seat member.

The transfer system may be repositionable between first and second states. With the transfer system in the first state, the surface is inclined downwardly from the transfer location toward the seat member. With the transfer system in the second state, the surface is inclined downwardly from the seat member towards the pickup unit.

The carrier is movable between a return position and a reloading position. In the return position, the carrier is located to receive in the receptacle thereon a workpiece moving from the seat member guidingly along the surface with the conveyor system in the second state. The carrier in the reloading position is situated adjacent to the first storage unit to permit transfer of a workpiece in the receptacle on the carrier to the first storage unit.

A repositioning element may be provided for selectively directing a workpiece from the carrier receptacle, with the carrier in the reloading position, to the first storage unit.

A reorienting element can be provided for selectively changing the orientation of the seat member from a first position wherein a workpiece is supportable on the seat member and a second position wherein a workpiece on the seat member moves under its own weight away from the seat member.

A discard receptacle can be provided for accepting a workpiece from the seat member as an incident of the seat member moving from its first position into its second position.

In one form, the workpiece mounting system includes an elongate arm carrying the seat member. The elongate arm is pivotable between first and second positions. At least one shifting assembly is provided. With the seat member adjacent to the first tool with the elongate arm in the first position, the shifting assembly can be operated to reposition a workpiece on the seat member into the operative state on the first tool.

The invention contemplates the above system in combination with a supply of a first type of workpiece in the first storage unit and a supply of a second type of workpiece in the second storage unit. The first and second types of workpieces can be different.

The invention also contemplates a method of manipulating elongate workpieces including the steps of providing a first supply of a first type of elongate workpiece at a first location, providing a second supply of a second type of elongate workpiece at a second location, providing a pickup unit, moving the pickup unit to a first pickup position, transferring a first workpiece from the first supply to a carrying position on the pickup unit, guidingly moving the

pickup unit and first workpiece to a delivery position, transferring the first workpiece in the carrying position away from the pickup unit in the delivery position to a first point of use, guidingly moving the pickup unit to a second pickup position, transferring a second workpiece from the second supply to a carrying position on the pickup unit, guidingly moving the pickup unit and second workpiece to a second delivery position, and transferring the second workpiece in the carrying position away from the pickup unit at the second delivery position to a second point of use.

The method may further include the steps of guidingly moving the pickup unit to a return position, transferring at least part of the first workpiece from the first point of use into the carrying position on the pickup unit in the return position, guidingly moving the pickup unit and the at least part of the first workpiece to a reloading position, and transferring the at least part of the first workpiece from the pickup unit in the reloading position to the first supply of elongate workpieces.

The method may further include the step of providing a first tool for performing a processing step on an elongate workpiece. The step of transferring the first workpiece may involve transferring the first workpiece to a mounting system. The method may further include the step of placing the first workpiece through the mounting system into an operative state on the first tool.

The method may further include the steps of performing a processing step on the first workpiece with the first tool including removing a portion of the first elongate workpiece and with the mounting system transferring the removed portion of the first elongate workpiece to a discard location.

The method may further include the step of providing a second tool for performing a processing step on an elongate workpiece. The step of transferring the second workpiece may involve transferring the second workpiece to the mounting system. The method may further include the step of placing the second workpiece through the mounting system into an operative state on the second tool.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side elevation view of a system for delivering elongate workpieces to a point of use according to the present invention;

FIG. **2** is a front elevation view of the inventive workpiece delivering system of FIG. **1**;

FIG. **3** is a plan view of the inventive workpiece delivering system of FIGS. **1** and **2**; and

FIG. **4** is a schematic representation of the inventive workpiece delivering system in FIGS. **1–3**.

DETAILED DESCRIPTION OF THE DRAWINGS

In FIGS. **1–4**, an automated system for delivering elongate workpieces, according to the present invention, is shown at **10**. The system **10** is designed to deliver elongate workpieces **12, 14, 16** from first, second, and third storage units **18, 20, 22**, one-by-one for processing selectively to first and second different machine tools **24, 26**. The machine tools **24, 26** perform any of a number of different conventional processing steps on the workpieces **12, 14, 16**. During the processing step, a part of the workpiece **12, 14, 16** may remain unused. Through the inventive system **10**, the remaining workpiece part is either discarded into a receptacle **28** or returned to the appropriate storage unit **18, 20, 22**.

The above handling operation is carried out through the coordinated operation of various subsystems. The workpieces **12, 14, 16** are moved from the storage units **18, 20, 22** through pickup units **30**. The pickup units **30** are controllably moved through a guide system **32** in a predetermined path from the storage units **18, 20, 22** to a transfer system **34**. Workpieces **12, 14, 16** are delivered through the transfer system **34** to a workpiece mounting system **36**, which a) positions workpieces **12, 14, 16** carried thereby selectively at the first and second tools **24, 26**, b) places the workpieces **12, 14, 16** in an operative state on the tools **24, 26**, and c) moves any unused portion of the workpiece **12, 14, 16** after the processing step either to the discharge receptacle **28** or to the guide system **32** for restocking on the storage units **18, 20, 22**. The individual subsystems will now be described in greater detail, below.

STORAGE UNITS 18, 20, 22

The three storage units **18, 20, 22** each have the same general construction. Thus, the discussion herein will be limited to exemplary storage unit **22**. It should be understood that any number of storage units is contemplated by the invention, i.e. one or greater than three.

The storage unit **22** consists of a workpiece support member **38** having a flat, upwardly facing surface **40** that is inclined downwardly towards the guide system **32**. The workpieces **16** are stored side-to-side, as shown in the figures, with the inclination of the surface **40** being such that the workpieces **16** move under their own weight downwardly towards the guide system **32**. Spaced blocking elements **42** abut to the lowermost workpiece **16** to prevent uncontrolled passage of the workpieces **16** to against the guide system **32**.

Downstream of the blocking elements **42**, repositionable gate elements **44** are provided. Each gate element **44** has a rod **46** that is repositionable between a retracted position, wherein the rod **46** does not project above the surface **40**, and an extended position, shown in FIG. **1**, wherein the workpiece **16** is consistently blocked thereby in a ready position, as shown in phantom lines in FIG. **1**.

To place the workpieces **16** abutted to the blocking elements **42** one-by-one into the ready position, a plurality of lifts **48** are provided immediately upstream of the blocking elements **42**. The lifts **48** each have a rod **50** which is extendable from beneath a workpiece **16** abutted to the blocking element **42** to a position wherein the workpiece **16** is elevated by the rod **50** to the height of the upper surface **52** of each blocking element **42**. As this occurs, the element **16** slides down the surface **52** and is from there guided by an angled surface **54** to against the surface **40** until the workpiece **16** abuts to the gate element **44** to be in the ready position. By then retracting the rod **46**, the workpiece **16** is released for reception by the pickup units **30**.

GUIDE SYSTEM 32

The guide system **32** carries a plurality of the pickup units **30**. Each pickup unit **30** is mounted on endless belt members **56** which are trained around spaced pulleys **58, 60**, which rotate around parallel axes **62, 64**, respectively. Through this arrangement, the pickup units **30** are caused to move in an endless path around the pulleys **58, 60**.

The pickup units **30** have a length aligned to be parallel with the pulley axes **62, 64** and the lengths of the workpieces **12, 14, 16** situated in the storage units **18, 20, 22**. In cross section, each pickup unit **30** includes a carrier **65** that is U-shaped, with a base **66** and legs **68, 70** projecting away from the base **66** and converging slightly away from the base **66**. The base **66** and legs **68, 70** cooperatively define a receptacle **72** for the workpieces **12, 14, 16**.

To pick up a workpiece **16**, the endless belts **56** are operated to situate the pickup unit **30** at A so that the free end **74** of the leg **68** is immediately at the level of, or slightly beneath, the bottom free end **76** of the surface **40**. By then operating the gate element **44** to retract the rod **46**, the workpiece **16** in the ready position slides under its own weight into a carrying position in the receptacle **72**. In the carrying position, the workpiece **16** is wedged into a V-shaped portion **78** of the receptacle **72** defined cooperatively by the base **66** and leg **68**.

The endless element **56** is then advanced, by operating a drive **79**, in the direction of the arrow **80**. The carrier **30** with the workpiece **16** therein moves upwardly until it reaches the top of the pulley **60** and then reverses direction. As this occurs, the workpiece **16** shifts from the V-shaped seat portion **78** into a V-shaped seat portion **82** defined cooperatively by the base **66** and leg **70**. The belts **56** are advanced to move the carrier downwardly until the pickup unit **30** reaches a delivery position as shown at B in FIG. **1** at a transfer location **84**.

TRANSFER SYSTEM 34

The transfer system consists of a pivotable member **86** with a flat, upwardly facing surface **88**. The member **86** is mounted for pivoting movement about an axis **90** that is parallel to the pulley axes **62**, **64**. Through a pivot drive **92**, the element **88** is pivotable between a first state, as shown in solid lines in FIG. **1**, and a second state, shown in phantom lines in FIG. **1**. In the first state, the surface **88** declines from the guide system **32** towards the mounting system **36**, whereas in the second state, the surface **88** declines from the mounting system **36** towards the guide system **32**, for reasons that will be explained below.

The pivot drive **92** consists of a cylinder **94** which operates an extendable ram **96** connected to the element **86**. Extension of the ram **96** moves the element **86** from its second state into its first state.

MOUNTING SYSTEM 36

The mounting system **36** consists of a vertically extending, elongate arm **98**. The arm **98** has arm sections **100**, **102** that are telescopingly mated, one within the other, to allow selective length adjustment. The relative positions of the arm sections **100**, **102** can be set by a conventional actuator **104**.

The upper end of the arm **98** carries a seat member **106**. The seat member **106** has a body **108** defining an upwardly opening, U-shaped seating surface **110** for a workpiece. The body **108** is pivotable relative to the arm section **100** between the solid line position in FIG. **1** and the phantom line position in that same figure. A reorienting element **112**, in the form of a cylinder, has a repositionable ram **114** that is extendable to move the body **108** from the solid line position to the phantom line position in FIG. **1**.

With the workpiece **16** and the pickup unit **30** at the transfer location **84** and the transfer system **34** in the first state, the free end **116** of the pickup unit leg **70** resides at the height of, or slightly above, one free end **118** of the surface **88**. By operating a plurality of repositioning elements **120**, extendable rods **122** thereon push the workpiece **16** out of the receptacle **72** and onto the surface **88**. The workpiece **16** then slides under its own weight in the direction of the arrow **124** to the opposite end **126** of the surface **88**. The arm sections **100**, **102** are relatively positioned so that with the body of the seat member **106** in the solid line position of FIG. **1**, the workpiece **16** can slide off of the surface end **126** into the receptacle **128** defined by the seating surface **110**.

The bottom end **130** of the arm **98** is pivoted for movement around an axis **132** that is parallel to the pulley axes **62**, **64**. Through a pivot drive **134**, the arm can be pivoted between the dotted line A and B positions shown in FIG. **1**. As this pivoting occurs, the reorienting element **112** can be operated to maintain the body **108** of the seat member **106** substantially in the upright, solid position of FIG. **1**.

By operating the drive **104** to pivot the arm **98** to the A position, the axis of the workpiece **16** aligns to be substantially parallel to the operating axis **134** for the tool **24**. Similarly, positioning of the arm **98** in the B position causes the axis of the workpiece **16** to align with the operating axis **136** for the tool **26**.

There are separate shifting assemblies **138**, **140** associated one each with the tools **24**, **26**, respectively. Each operates in the same manner. Exemplary shifting assembly **136** has an endless belt **142** carrying a releasable gripper **144**. The belt **142** is trained around spaced pulleys **146**, **148** which rotate around parallel axes **150**, **152**, which are orthogonal to the tool axis **136**. By operating a drive **154**, the gripper **144** is movable with the belt **142** in the direction of the double-headed arrow **156**, i.e. parallel to the tool axis **136**.

With the arm **98** in the B position of FIG. **1**, the drive **154** can be operated to advance the workpiece **16** into the operating state on the tool **26**, shown in FIG. **3**. By then retracting the gripper **144** through operation of the drive **154**, and repositioning the arm **98**, a desired processing step can be carried out without interference from the gripper **144**.

In some operations, the workpiece **16** is cut so that there is a useable portion that is to be machined and a remaining unused portion. The arm **98** can be repositioned so that the seating member **106** accepts the remaining, unused portion of the workpiece **16**. The arm **104** can then be returned to the solid line position in FIG. **1**. By placing the transfer system **34** in the second state, i.e. phantom line position, with the arm sections **100**, **102** relatively in the phantom line position of FIG. **1**, the body **108** can be repositioned, i.e. tipped, through the reorienting element **112** to cause the remaining portion of the workpiece **16** to move under its own weight in the direction of the arrow **158** along the surface **88** of the element **86** back towards the guide system **32**.

To accept the remaining, unused portion of the workpiece **16**, one of the pickup units **30** is moved to a return position, shown at C in phantom lines in FIG. **1**. The remaining portion of the workpiece **16** then moves into the receptacle **72**. By advancing the belt **56** reversely in the direction of the arrow **158**, the pickup unit **30** with the remaining portion of the workpiece **16** can be situated in a reloading position, which in this case is the same as the pickup position, at the pickup unit **22**. By operating the repositioning element **160**, a ram **162** is extended to push the remaining portion of the workpiqce **16** out of the receptacle **72** and on to the surface **40** for re-storage on the first unit **22**. The repositioning element **160** could move the remaining portion of the workpiece **16** to the ready position, previously described. Diverting structure could be incorporated to direct the remaining portion of the workpiece **16** to any location on the surface **40**.

If the remaining portion of the workpiece **16** is determined to be unusable, it can be delivered to the discard receptacle **28** directly from the seating member **106** by tipping the body **108** through the reorienting element **112** with the body **108** of the seating member **106** residing beneath the element **86**. An inclined deflecting element **164** is provided to intercept the falling portion of the workpiece element **16** and to guide it into the receptacle **28**.

With the inventive system, the workpieces from any of the three storage units **18**, **20**, **22** can be delivered to either tool **24**, **26** and in any order. The remaining portion of the workpieces **12**, **14**, **16** after processing can either be discarded or returned to the storage units **18**, **20**, **22**. Accordingly, a single system can be used to deliver one-by-one any desired workpiece configuration to selected processing tools **24**, **26**. Through a central controller **166**, a programmed, automatic operation of the system **10** can take place. Movement of the multiple pickup units **30** with the various coordinated subsystems can be effected through the controller **166** to produce an efficient overall operation. The specific design of the central controller **166** is within the knowledge of one skilled in this art.

The foregoing disclosure of specific embodiments is intended to be illustrative of the broad concepts comprehended by the invention.

I claim:

1. A system for delivering elongate workpieces to a point of use, said workpiece delivering system comprising:

a first storage unit for a supply of a first type of elongate workpiece;

a pickup unit for selectively picking up elongate workpieces one-by-one from the first storage unit; and

a guide system for guidingly moving the pickup unit with a workpiece picked up thereby to a predetermined transfer location,

wherein the first storage unit comprises a surface for guiding workpieces moving under the force of gravity toward a ready position from which a workpiece can be transferred to the pickup unit,

wherein the guiding surface comprises an inclined surface and the first storage unit comprises a blocking element against which a workpiece moved downwardly along the guiding surface abuts, and a lift for selectively directing a workpiece abutted to the blocking element upwardly to allow movement thereof past the blocking element to the ready position.

2. The workpiece delivering system according to claim **1** in combination with a tool for performing a processing step on a workpiece, said workpiece delivering system further comprising a workpiece mounting system for conveying a workpiece from the transfer location into an operative state on the tool.

3. The workpiece delivering system according to claim **2** wherein the workpiece mounting system comprises a seat member for supporting a workpiece and a transfer system for moving a workpiece from the transfer location to a supported position on the seat member.

4. The workpiece delivering system according to claim **3** wherein the transfer system comprises a surface that is inclined downwardly from the transfer location toward the seat member to cause a workpiece to be guided under its own weight in movement between the transfer location and the seat member.

5. The workpiece delivering system according to claim **1** in combination with first and second tools for performing separate processing steps on a workpiece, said workpiece delivering system further comprising a workpiece mounting system for conveying a workpiece from the transfer location into an operative state selectively on one of the first and second tools.

6. The workpiece delivering system according to claim **1** further comprising a second storage unit for a second supply of elongate workpieces, the pickup unit being capable of selectively picking up elongate workpieces one-by-one from the first and second storaae units, in combination with a supply of a first type of workpiece in the first storage unit and a supply of a second type of workpiece in the second storage unit.

7. The workpiece delivering system according to claim **6** wherein the workpieces in the first supply of workpieces are different than the workpieces in the second supply of workpieces.

8. A system for delivering elongate workpieces to a point of use, said workpiece delivering system comprising:

a first storage unit for a supply of a first type of elongate workpiece;

a second storage unit for a supply of a second type of elongate workpiece;

a pickup unit for selectively picking up elongate workpieces one-by-one from the first and second storage units; and

a guide system for guidingly moving the pickup unit with a workpiece picked up thereby to a predetermined transfer location,

wherein the first storage unit comprises a surface for guiding workpieces moving under the force of gravity toward a ready position from which a workpiece can be transferred to the pickup unit,

wherein the guiding surface comprises an inclined surface and the first storage unit comprises a blocking element against which a workpiece moved downwardly along the guiding surface abuts, and a lift for selectively directing a workpiece abutted to the blocking element upwardly to allow movement thereof past the blocking element to the ready position.

9. The workpiece delivering system according to claim **8** wherein the first storage unit comprises a gate element that is placeable selectively in a) an extended position wherein the gate element blocks a workpiece in the ready position and b) a release position wherein a workpiece in the ready position is allowed to move to the pickup unit.

10. The workpiece delivering system according to claim **9** wherein the pickup unit comprises at least one carrier with a receptacle for a workpiece and the guide system comprises a guide system for moving the one carrier between a) a pickup position wherein a workpiece can be transferred from the first storage unit to the carrier receptacle and b) a delivery position at the transfer location.

11. The workpiece delivering system according to claim **10** wherein the guide system comprises a member that moves around a pair of spaced pulleys in an endless path and the carrier is attached to the member to follow movement of the member to thereby move between the pickup and delivery positions.

12. In combination:

a) a system for delivering elongate workpieces to a point of use, said workpiece delivering system comprising:

a first storage unit for a supply of a first type of elongate workpiece;

a second storage unit for a supply of a second type of elongate workpiece;

a pickup unit for selectively picking up elongate workpieces one-by-one from the first and second storage units; and

a guide system for guidingly moving the pickup unit with a workpiece picked up thereby to a predetermined transfer location; and

b) a tool for performing a processing step on a workpiece,

said workpiece delivering system further comprising a workpiece mounting system for conveying a workpiece from the transfer location into an operative state on the tool,

wherein the workpiece mounting system comprises a seat member for supporting a workpiece and a transfer system for moving a workpiece from the transfer location to a supported position on the seat member,

wherein the transfer system comprises a surface that is inclined downwardly from the transfer location toward the seat member to cause a workpiece to be guided under its own weight in movement between the transfer location and the seat member,

wherein the transfer system is repositionable between first and second states, with the transfer system in the first state, the surface is inclined downwardly from the transfer location toward the seat member, and with the transfer system in the second state, the surface is inclined downwardly from the seat member towards the pickup unit,

said pickup unit comprising at least one carrier with a receptacle for a workpiece that is movable between a return position and a reloading position, said carrier in the return position located to receive in the receptacle a workpiece moving from the seat member guidingly along the surface with the conveyor system in the second state, the carrier in the reloading position situated adjacent to the first storage unit to permit transfer of a workpiece in the receptacle in the carrier to the first storage unit.

13. The workpiece delivering system according to claim **12** including a repositioning element for selectively directing a workpiece from the carrier receptacle with the carrier in the reloading position to the first storage unit.

14. The workpiece delivering system according to claim **12** including a reorienting element for selectively changing the orientation of the seat member from a first position wherein a workpiece is supportable on the seat member and a second position wherein a workpiece on the seat member moves under its own weight away from the seat member.

15. The workpiece delivering system according to claim **14** in combination with a discard receptacle for accepting a workpiece from the seat member as an incident of the seat member moving from the first position into the second position.

16. In combination:

a) a system for delivering elongate workpieces to a point of use, said workpiece delivering system comprising:
   a first storage unit for a supply of a first type of elongate workpiece;
   a second storage unit for a supply of a second type of elongate workpiece;
   a pickup unit for selectively picking up elongate workpieces one-by-one from the first and second storage units; and
   a guide system for guidingly moving the pickup unit with a workpiece picked up thereby to a predetermined transfer location; and

b) first and second tools for performing separate processing steps on a workpiece,
   said workpiece delivering system further comprising a workpiece mounting system for conveying a workpiece from the transfer location into an operative state selectively on one of the first and second tools,
   wherein the workpiece mounting system comprises an elongate arm with a seat member for a workpiece thereon, said elongate arm being pivotable between first and second positions, and at least one shifting assembly, the seat member being situated so that a workpiece on the seat member is adjacent to the first tool with the elongate arm in the first position whereupon the shifting assembly can be operated to reposition a workpiece on the seat member into the operative state.

17. A method of manipulating elongate workpieces, said method comprising the steps of:

providing a first supply of a first type of elongate workpieces at a first location;

providing a pickup unit on an endless member trained around spaced first and second pulleys;

moving the pickup unit to a first pickup position;

transferring a first workpiece from the first supply to a carrying position on the pickup unit;

guidingly moving the pickup unit and first workpiece from the first pickup position by advancing the endless belt member continuously in one direction around the spaced pulleys to cause the pickup unit with the first workpiece in a carrying position thereon to first travel upwardly and thereafter downwardly a substantial distance to a delivery position; and

transferring the first workpiece in the carrying position away from the pickup unit at the delivery position to a first point of use.

18. The method of manipulating elongate workpieces according to claim **17** including the step of providing a first tool for performing a processing step on an elongate workpiece and the step of transferring the first workpiece comprises the step of transferring the first workpiece to a mounting system and including the step of placing the first workpiece through the mounting system into an operative state on the first tool.

19. The method of manipulating elongate workpieces according to claim **18** including the steps of providing a second supply of a second type of elongate workpieces at a second location, guidingly moving the pickup unit to a second pickup position, transferring a second workpiece from the second supply to a carrying position on the pickup unit, guidingly moving the pickup unit and second workpiece to a second delivery position, transferring the second workpiece in the carrying position away from the pickup unit at the second delivery position to a second point of use, and providing a second tool for performing a processing step on an elongate workpiece, and the step of transferring the second workpiece comprises the step of transferring the second workpiece to the mounting system, and including the step of placing the second workpiece through the mounting system into an operative state on the second tool.

20. The workpiece delivering system according to claim **17** wherein the first and second pulleys each have a rotational axis, the first rotational axis is above the second rotational axis and extends in a horizontal direction and the step of guidingly moving the pickup unit and first workpiece comprises advancing the belt member downwardly so that the pickup unit with the first workpiece in a carrying position thereon resides below the first axis with the pickup unit and first workpiece in the delivery position.

21. A method of manipulating elongate workpieces, said method comprising the steps of:

providing a first supply of a first type of elongate workpieces at a first location;

providing a second supply of a second type of elongate workpieces at a second location;

providing a pickup unit;

moving the pickup unit to a first pickup position;

transferring a first workpiece from the first supply to a carrying position on the pickup unit;

guidingly moving the pickup unit and first workpiece to a delivery position;

transferring the first workpiece in the carrying position away from the pickup unit at the delivery position to a first point of use;

guidingly moving the pickup unit to a second pickup position;

transferring a second workpiece from the second supply to a carrying position on the pickup unit;

guidingly moving the pickup unit and second workpiece to a second delivery position;

transferring the second workpiece in the carrying position away from the pickup unit at the second delivery position to a second point of use;

guidingly moving the pickup unit to a return position;

transferring at least a part of the first workpiece from the first point of use into the carrying position on the pickup unit;

guidingly moving the pickup unit and the at least part of the first workpiece to a reloading position; and

transferring the at least part of the first workpiece in the reloading position from the pickup unit to the first supply of elongate workpieces.

22. A method of manipulating elongate workpieces, said method comprising the steps of:

providing a first supply of a first type of elongate workpieces at a first location;

providing a second supply of a second type of elongate workpieces at a second location;

providing a pickup unit;

moving the pickup unit to a first pickup position;

transferring a first workpiece from the first supply to a carrying position on the pickup unit;

guidingly moving the pickup unit and first workpiece to a delivery position;

transferring the first workpiece in the carrying position away from the pickup unit at the delivery position to a first point of use;

guidingly moving the pickup unit to a second pickup position;

transferring a second workpiece from the second supply to a carrying position on the pickup unit;

guidingly moving the pickup unit and second workpiece to a second delivery position;

transferring the second workpiece in the carrying position away from the pickup unit at the second delivery position to a second point of use;

providing a first tool for performing a processing step on an elongate workpiece,

wherein the step of transferring the first workpiece comprises the step of transferring the first workpiece to a mounting system;

placing the first workpiece through the mounting system into an operative state on the first tool; and

performing a processing step on the first workpiece with the first tool including removing a portion of the first elongate workpiece and with the mounting system transferring the removed portion of the first elongate workpiece to a discard location.

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